October 12, 2020

VIA ELECTRONIC FILING

Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
445 Twelfth Street, SW
Washington, DC 20554

Re: **Report Submission,** Expanding Flexible Use of the 3.7-4.2 GHz Band, GN Docket No. 18-122

Dear Ms. Dortch:

Please find attached the report of the C-Band Technical Working Group 4 (TWG-4) on 5G/CBRS Coexistence.

TWG-4 is one of four technical working groups that is part of a multi-stakeholder group established in response the Federal Communications Commission's encouragement in its February 2020 C-Band Report and Order.[1] The Commission encouraged stakeholders to develop a multi-stakeholder group to address "coexistence issues related to terrestrial wireless operations below 3.7 GHz"[2], among others.

Pursuant to Section 1.1206 of the Commission's rules, a copy of this letter is being filed in the Commission's Electronic Comment Filing System. Please do not hesitate to contact the undersigned with any questions.

Respectfully Submitted,

/s/ PJ Jayawardene
PJ Jayawardene
Senior Director, Head of 5G R&D, Charter Communications

/s/ Peter Tenerelli
Peter Tenerelli
Distinguished Member of the Technical Staff, Verizon

Attachment

[1] See Expanding Flexible Use of the 3.7 to 4.2 GHz Band, Report and Order and Order of Proposed Modification, 35 FCC Rcd 2343 (2020) ("C-Band Order").
[2] Id. ¶ 333.

Report of the
C-Band Technical Working Group 4
5G / CBRS Coexistence

Co-chairs:

PJ Jayawardene, Charter Communications

Pete Tenerelli, Verizon

Report Date: October 06, 2020

Abstract:

In the Federal Communications Commission's (Commission) Report & Order, *Expanding Flexible Use of the 3.7 to 4.2 GHz Band,*[1] (C-Band Order), the Commission "encourage[s] the industry to convene a group of interested stakeholders to develop a framework for interference prevention, detection, mitigation, and enforcement in the 3.7-4.2 GHz band.
One of these multi-stakeholder working groups is Technical Working Group #4 (TWG4), focused on Coexistence between the 3.7 GHz Service and Citizens Broadband Radio Service (CBRS).

This report provides the findings and outcomes, based upon the work of TWG4.

[1] See Expanding Flexible Use of the 3.7 to 4.2 GHz Band, Report and Order and Order of Proposed Modification, 35 FCC Rcd 2343 (2020) ("C-Band Order")

Revision History

Version #	Editor	Edit Date	Comments, changes
01	Pete Tenerelli	8-28-2020	First Draft, framework
02	PJ Jayawardene	9-9-2020	Added content including Acknowledgements, edits on Approach section, added content to Summary of Findings and Outcomes. Added Gillis' Technical Details of SoW Item2 (Use cases). Integrated Solondz comments
03	Pete Tenerelli	9-16-20	Editing for clarity in Background, Summary of Findings and Outcomes. Integrated Graves's comments.
04	PJ Jayawardene, Pete Tenerelli	9-22-20	Added section on Impact of relative levels of network loading on CBRS / C-Band networks that are fully synchronized Added section on SOW Item #4 Coexistence Options Added section on SOW Item #5 Coexistence Management and Coordination Added section on SOW Item #6 Enforcement of Coexistence Practices Minor edits of grammar, insertion of sub-section headings for clarity.
05	Pete Tenerelli	9-24-20	Made edits, inserted comments, inserted to-do's related to the 9-24-20 TWG4 call. Inserted content into Meeting Minutes Appendix. Inserted Coexistence Options presentation from 7-31-2020 Updated Dynamic Simulation presentation from to the newest (version 6.7)
06	Cameron Gillis, Ramneek Bali, Pete Tenerelli	9-30-20	Added 9-24-20 meeting minutes Added list of attendees into Appendix Added Statement of Work section Addressed to-do's from 9-24-20 meeting Multiple edits for clarity
07	Joe Attanasio Pete Tenerelli Shahzad Bashir Kumar Balachandran Patrick Welsh	10-1-2020	Edits to Global coexistence section Added further details into Dynamic Simulation Summary section Multiple edits and insertions
07.1	TWG4 team on-screen editing	10/2/2020	Onscreen editing and reconciling of markups. We made edits through section 4e, except the final subsection "Hybrid approaches" We will continue working on the document from this point on Monday 10-5-2020

Version #	Editor	Edit Date	Comments, changes
07.2	Masoud Olfat, Cameron Gillis, PJ Jayawardene, Pete Tenerelli	10/4/2020	Double-checked the loss values in Section 4) c) ii) Dynamic Simulation Analysis for compliance with the originating presentation. Added footnotes. Duplicated content from "Summary" subsections (in section 4) to "Technical Details" sections in the Appendices Slimmed down the hybrid approaches summary in Section 4e
08	TWG4 team on-screen editing	10/5/2020	Minor edits, mostly accepting proposed markups from previous versions Added cover page and abstract Repaired headers and footers Fixed cross-reference errors

Table of Contents

1. Acknowledgements

The co-chairs of TWG4 would like to thank all the participants representing multiple industry bodies, vendors and service providers for the active dialog and debate that steered us towards the material presented herein. We would also like to extend our gratitude towards these contributors of the study items and authors of the sub-sections of the final report.

- Kumar Balachandran (Ericsson)
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2. Background

In the Federal Communications Commission's (Commission) Report & Order, *Expanding Flexible Use of the 3.7 to 4.2 GHz Band,*[2] (C-Band Order), the Commission "encourage[s] the industry to convene a group of interested stakeholders to develop a framework for interference prevention, detection, mitigation, and enforcement in the 3.7-4.2 GHz band". The Commission "also encourage[s] any multi-stakeholder group that is formed to consider best practices and procedures to address issues that may arise during the various phases of the C-band transition and to consider coexistence issues related to terrestrial wireless operations below 3.7 GHz. It reasoned that a multi-stakeholder group "could provide valuable insight into the complex coexistence issues in this band and provide a forum for the industry to work cooperatively towards efficient technical solutions to these issues."[3]

Shortly after the C-Band Order was adopted, a representative group of industry associations and companies (the "Multi-Stakeholder Group" or "MSG") joined together to collaboratively develop the preliminary roadmap for four TWGs to engage in the technical work necessary to address the coexistence and relocation logistics issues described in the Order. The MSG includes representatives from approximately 60 different companies and associations across a wide range of stakeholder interests—including aviation, broadcasters and content companies, cable providers, satellite operators and filter manufacturers, Wireless Internet Service Providers, Citizens Broadband Radio Service stakeholders and Spectrum Access System providers, wireless services providers (nationwide, rural, and regional) and manufacturers, and other entities and representative associations—with representatives engaging in one or more of the TWGs and often including multiple representatives from within each organization.[4] This resulted in four Technical Working Groups (TWGs). The TWGs include TWG1, 3.7 GHz Service / FSS Coexistence, TWG2, FSS Relocation, TWG3, 3.7 GHz Service / Radio Altimeter Coexistence, and TWG4, 3.7 GHz Service / CBRS Coexistence.

This report provides the findings and outcomes, recommendations from Technical Working Group #4 (TWG4), focused on Coexistence between the 3.7 GHz Service and Citizens Broadband Radio Service (CBRS).

The TWG4 was co-chaired by PJ Jayawardene from Charter Communications and Pete Tenerelli from Verizon. It includes 52 participants from the following companies and associations: AT&T, CableLabs, CCA, Charter, Comcast, Commscope, CTIA, Ericsson, Federated Wireless, GCI, Google, Midco, Nokia, NCTA, Nokia, Qualcomm, Samsung, T-Mobile, US Cellular, Verizon, Viaero, Windstream, and WISPA.

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[2] See Expanding Flexible Use of the 3.7 to 4.2 GHz Band, Report and Order and Order of Proposed Modification, 35 FCC Rcd 2343 (2020) ("C-Band Order")

[3] Expanding Flexible Use of the 3.7 to 4.2 GHz Band, Report and Order and Order of Proposed Modification, ¶333 Id. ¶ 333.

[4] See https://ecfsapi.fcc.gov/file/1092402222337/200924%20C-Band%20Multi-Stakeholder%20Group%20Meeting%20Ex%20Parte.pdf

3. Approach and Report Structure

This section describes the approach we followed in the execution of the TWG4 activities.

a. Approach

Our approach to TWG4 was to first identify areas for analysis and discussion. We then made a concerted effort to bring the identified topics to conclusion by presenting a detailed problem statement and a solution. The criteria for consideration of a coexistence implementation included evaluation of technical feasibility, deployment considerations, and technical effectiveness. The resulting document was a Statement of Work (SoW), described below. Following this, TWG4 members assisted with the analysis of the relevant topics, sharing information via e-mail and during our weekly meetings.

The aim of TWG4 was to seek areas of agreement, upon which we could make recommendations.

In cases where we did not reach agreement, we outlined the aspects of disagreement.
Given the limited available time, we generally found that the scope of the group was ambitious, perhaps overly so. As such, we have abbreviated various analyses that the group studied. We note these abbreviations in the individual subsections of this report.

b. Report Structure

TWG4 developed a Statement of Work (SoW) shortly after the group's formation. We used this to SoW to guide the activities, analysis, and discussion amongst the group. The latest version of the SoW is version 1.4. The main topics covered in the SoW are the following:

1. Identify and Confirm Areas of Concern
2. Define Use Cases
3. Quantifying the impacts of the areas of concern
4. Coexistence options
5. Coexistence management and coordination
6. Enforcement of coexistence practices

We presented findings, outcomes, and discussions using section headings of each of the six SoW topics.

4. Summary of Findings and Outcomes

This section summarizes the findings and outcomes related to the topics taken up by TWG4. For details on each SoW topic, please see sections that follow below.

While every effort was made to address the major coexistence challenges, one underlying challenge was that the intra-band coexistence framework within CBRS and C-Band themselves were still yet to be defined or were in their early stages of exploration.

a. SoW Item #1: Identify and Confirm Areas of Concern

First, at the onset of TWG4, the group anchored the following areas as primary areas of investigation.

a. Absence of TDD synchronization between C-Band and CBRS operators and Intra-C-Band operators
b. Impacts of Out of band emissions between CBRS and C-Band
c. Receiver overload / co-location considerations
d. Impact between non-3GPP operations in the CBRS band and C-Band Operations
e. Potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions

Topics (a), (b) and (c) were evaluated in static analysis for the worst case scenario, simulation results considering synchronous, semi-synchronous and unsynchronized networks, and characterization of unsynchronized networks using CBRS intra-band field measurements.

The TWG4 concluded that the absence of synchronization could mutually degrade the performance of both CBRS and C-Band networks to varying degrees.

Regarding topic (d) above, TWG4's understanding is that the CBRS Alliance or Wireless Innovation Forum (WInnForum) are examining how non-3GPP technologies can support TDD synchronization with 3GPP technologies. The current dominant non-3GPP technologies in the CBRS band are WiMAX and a proprietary technology developed by Cambium Networks. The current status and roadmap to allow non-3GPP technology TDD synchronization is that WiMAX in still in progress and the feasibility analysis for the Cambium Networks protocol is complete. The subsequent step is the CBRS Alliance or WInnForum would need to perform the necessary protocol development.

Regarding topic (e) above, this is being investigated by the CBRS Alliance or WInnForum so TWG4 did not work on this topic.

b. SOW Item #2 Define Use Cases

TWG4 performed an analysis to assess the possible combinations of use cases and found that the number was over one million. Since the analysis of each use case is hours-long, evaluating the full set of use cases was impractical. Therefore TWG4 worked on reducing the number to a more manageable level. The group performed this by limiting the analysis to C-Band to CBRS base station to base station analysis and prioritizing the most prevalent five (5) use cases.

For further details with supporting Use Case analysis spreadsheet, please see Appendix B: Technical Details of SoW Item 2 - Define Use Cases.

c. SOW Item #3: Quantifying the impacts of the areas of concern

TWG4's Statement of Work described this task excerpted directly from the SoW as follows:

Quantify the impacts of the areas of concern in the subsections below. Account for the following considerations during these efforts:

- *Use realistic equipment specifications and filter characteristics*
- *Consider existing levels of intra-band interference*
- *Consider existing interference mitigation techniques*

a. Deterministic and statistical analysis of:
i. Asynchronous TDD operation
ii. Out of band emissions
iii. Receiver overload and co-location
b. Non-3GPP solutions:
i. Determine the non-3GPP use cases being employed within CBRS and their usage across the band
ii. Quantify the impact between non-3GPP use cases and 3GPP use cases and the probability of the impact over the next 3-5 years as 3GPP based solutions gather scale

Most of TWG4's work to quantify interference performance impacts focused on examining the effect of varying degrees of TDD Synchronization between the networks under study.

The TWG4 concluded that the absence of synchronization could mutually degrade the performance of both CBRS and C-Band networks to varying degrees.

In the absence of information on the characteristics of commercial C-Band equipment, TWG4 opted for providing a range of specifications to help provide some sensitivity analysis on how a change in specification values might have varying degrees of impact to co-existence performance.

i. Deterministic Analysis

This section summarizes the deterministic analysis and key findings of interference between unsynchronized CBRS and C-Band networks.

The following four scenarios of mutual impact exist between CBRS and C-Band:

1- BS to BS interference: BS downlink to BS uplink
2- UE to UE interference: UE uplink to UE downlink
3- BS to UE interference: BS downlink to UE downlink
4- UE to BS interference: UE uplink to BS uplink

TWG4 reported on the BS to BS interference as a result of its deterministic analysis.

Findings:

- The primary area of concern was the BS-BS interference, and the findings from the deterministic analysis was that the interference threshold, characterized by an ACIR target range, as published in the 3GPP specification[5] was exceeded when the unsynchronized adjacent networks base stations were nearby to each other.
- The analysis found that a separation distance of 100 – 250 m would be required in order to avoid exceeding the interference threshold, see chart below. This outcome (as seen as "Urban NLos_A in the chart) is based upon the use of a 25 dB interference reduction to account for beamforming efficiency

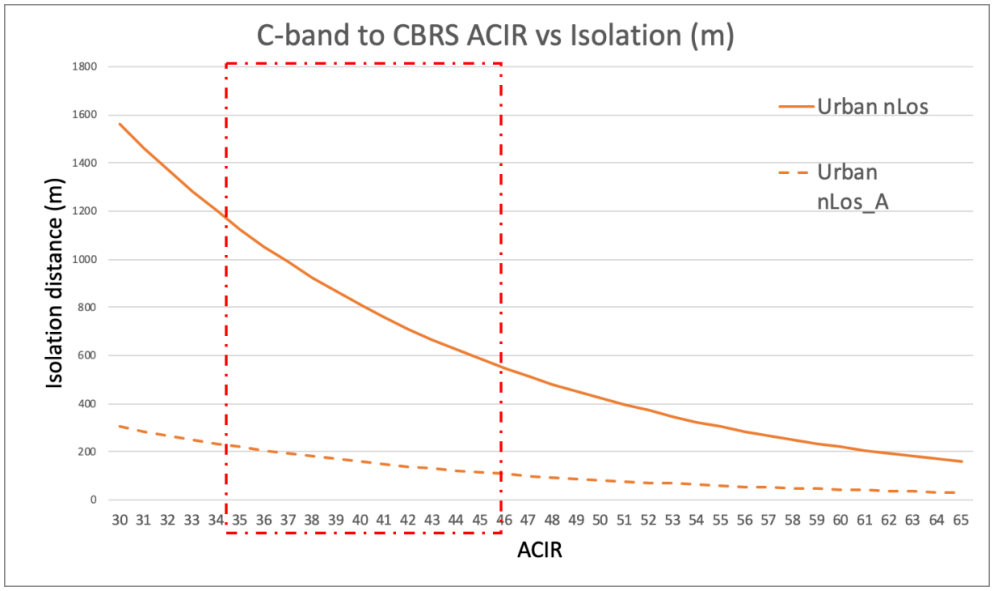


Figure 1 Deterministic analysis- worst case C-Band base station to CBRS base station interference analysis

[5] See 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; NR; Base Station (BS) radio transmission and reception, 3GPP TS 38.104.
https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3202

Caveats

There were comments from the group regarding the applicability of some aspects of the analysis, including the following:

- The 3GPP blocking spec used in our analysis is meant for the certification of equipment, and is not related to network performance in the field. A capacity simulation is in order, calculating throughput reductions.
- The 6 dB interference spec is an equipment testing spec, and does not mean the receiver will get desensitized. This is a corner case and the use of this value doesn't indicate how frequently this situation could occur. In contrast, a standardized 3GPP method that quantifies how often unacceptable degradation would occur in a given scenario. Note that the 3GPP method assumes a synchronized TDD.
- Others commented that the current set of parameter values are suitable for worst-case.
- There was discussion about the lack of realistic equipment specifications and the applicability of using FCC limits for e.g. out of band emissions (OOBE) and maximum effective isotropic radiated power (EIRP), since we expect that actual equipment will perform better than FCC limits and the likely use of lower power in urban areas. The interference impacts due to unsynchronized aspects are also applicable to within the CBRS band.

For further details, including analysis spreadsheet please refer to Appendix C, Sub-section (a): Technical Details of SoW Item #3 quantifying the impacts of the areas of concern.

ii. Dynamic Simulation Analysis

This section summarizes the Dynamic Simulation Analysis and key findings of interference from C-Band to CBRS Band under unsynchronized, semi-synchronized, and synchronized conditions.

The Dynamic Simulation Analyses used varying degrees of synchronization, as described in the table below. Note that both of the CBRS and C-Band systems were transmitting with "full buffer" (i.e. always had traffic to send over the air interface):

Scenario	CBRS Downlink↓	CBRS Uplink↑	C-Band Downlink↓	C-Band Uplink↑	Scenario Comments
100% Unsynched TDD	0%	100%	100%	0%	Won't occur in the field, provides boundary condition.
Semi-Synched TDD	70%	30%	30%	70%	50% probability of frame collision.
Fully Synced TDD	70%	30%	70%	30%	Co-sited BSs. Vertical separation 5m.

In each scenario, the analysis examined the impact of varying ACIR (Adjacent Channel Interference Ratio) {46 dB, 58 dB} and varying distance between CBRS and C-Band sites {100m, 300m}. Note that the co-sited, fully synchronized scenario assumed 5m of vertical separation.

All degradations are relative to the "baseline" case where only CBRS are operating (no C-Band transmissions).

Findings:

- Degradation appeared predominantly in the CBRS uplink, (not in the CBRS downlink). This degradation is further described below in terms of throughput reduction.

Fully unsynchronized scenario:
This is the worst case amount of synchronization (never synchronized)

Scenario	CBRS Downlink↓	CBRS Uplink↑	C-Band Downlink↓	C-Band Uplink↑	CBRS Uplink Throughput Degradation
100% Unsynched TDD	0%	100%	100%	0%	• **300m separation and 58 dB ACIR**: Performs almost as well as the baseline (CBRS only network). Cell center loss: 4.3% Cell edge loss: 5.5% • **300m separation and 46 dB ACIR**: Manageable drop in performance for the cell center but a more significant drop for cell edge users. Cell center loss: 11.6% Cell edge loss: 69.1%

Semi-synchronized scenario:
This is a more likely scenario to occur with unsynchronized networks.

Scenario	CBRS Downlink↓	CBRS Uplink↑	C-Band Downlink↓	C-Band Uplink↑	CBRS Uplink Throughput Degradation
Semi-Synched TDD	70%	30%	30%	70%	• **300m separation and 58 dB ACIR**: Almost no loss relative to the baseline Cell center loss: 6.9% Cell edge loss: 2.7% • **300m separation and 46 dB ACIR**: Manageable drop in performance for the cell center but a more significant drop for cell edge users. Cell center loss: 20% Cell edge loss: 54% **100m separation and 58 dB ACIR**: Manageable drop in performance for the cell center but a more significant drop for cell edge users. Cell center loss: 18% Cell edge loss: 54%

Fully Synchronized, co-sited scenario (5m vertical separation):

Scenario	CBRS Downlink↓	CBRS Uplink↑	C-Band Downlink↓	C-Band Uplink↑	CBRS Uplink Throughput Degradation
Fully Synced TDD	70%	30%	70%	30%	• **46 dB ACIR**: No degradation Cell center loss: 0.34% Cell edge loss: 2.1%

Conclusions:

- A distance of 300m between C-Band and CBRS sites appears to provide sufficient protection for CBRS Base Stations to operate with little or no degradation.
- Deploying fully synchronized networks and a 5m vertical separation between CBRS and C-Band Base stations could potentially provide sufficient isolation to protect CBRS uplink and downlink operations with no degradation.

For further details, including supporting presentation, please refer to Appendix C, Sub-section (b): Technical Details of SoW Item #3 quantifying the impacts of the areas of concern.

iii. Measurements in an unsynchronized TDD CBRS Network.

This campaign was based upon measurements within the CBRS frequency band and between CBRS transceivers. It assessed performance impacts by varying the geographic and spectral distance between the victim and aggressor within unsynchronized or synchronized TDD CBRS networks.

The aggressors (Base Stations or UEs) and Victim UE were all indoors while the victim BS was outdoors.

Findings:

- When networks are synchronized, performance is similar regardless of geographic and spectral separation.
- When the networks are unsynchronized, there is degraded throughput when the network elements are closer in geographic and spectral separation.
    - For the indoor to outdoor case, 20m separation is sufficient to avoid degradation. For the indoor to indoor case, a 20m and 10 MHz separation is sufficient to avoid degradation.

TWG4 discussed the applicability of these CBRS-CBRS measurements with reference to the working group mandate of CBRS/C-Band coexistence and noted that the general trends are likely similar, even if the quantitative results would vary.

For the presentation supporting this section, please refer to Appendix C, Sub-section (c): Technical Details of SoW Item #3 quantifying the impacts of the areas of concern.

iv. Impact of relative levels of network loading on CBRS / C-Band networks that are fully synchronized

This section summarizes the coexistence analysis of C-Band and CBRS networks that are fully synchronized.

The simulation examined the impact of varying the relative network utilization levels in the respective networks (Note that, the cell edge targets were 5 Mbps for downlink and 1 Mbps for uplink in this study):

- First, it looked at interference levels within CBRS (with C-Band "switched off"),
- Next, it examined the impact of C-Band on the CBRS network for both Cat A and Cat B CBSDs.

Regarding the transmitting and receiving network elements:

- **CBRS Base stations** were outdoor (Cat A & Cat B) **CBRS UEs** were both indoor & outdoor
- **C-Band Base stations** were outdoor macro

Findings:

- In all cases, the degradation to capacity was on the downlink, but not on the uplink.
- With fully synchronized TDD network, when the C-Band is the aggressor, a very high network utilization (~90%) is needed to severely impact CBRS so the interference levels are manageable under typical network scenarios. Modifying the relative antenna orientations of the victim/aggressor has a significant positive impact in reducing interference.

For the presentation supporting this section, please refer to Appendix C, Sub-section (d): Technical Details of SoW Item #3 quantifying the impacts of the areas of concern.

d. SOW Item #4 Coexistence Options

This section describes TWG4's analysis of coexistence options.

TWG4 examined coexistence options, including a survey of what is happening globally in the mid-band TDD networks (2, 3, and 4 GHz bands). We also looked at various global regulatory and operator's intra-band coexistence methods see Appendix D.

The following summarizes the two presentations on the topic:

- Licensing was a mix of allocation of spectrum to the operators and auctioning of spectrum.
- The use of guard bands was rare, except for one 4G case.
- In 5G networks, coordination among operators is the method for deciding TDD parameters. The Chinese regulator was involved in organizing negotiations. In 4G networks, there was more regulator involvement including three mandating a set of TDD parameters.
- In many countries that we analyzed, with or without a regulatory mandate, operators are collaborating in the choice of specific TDD configuration parameters, to be applied in-common among all networks using adjacent unpaired spectrum allocations.
    - Japan's ministry of communications guidelines recommends that operators support the industry-consensus TDD parameters.
    - China's MIIT recommends synchronization for adjacent TDD systems, and requests that operators negotiate with one another to identify specify synchronization schemes
    - Operators in several European countries have selected a preferred TDD pattern, with the encouragement of local regulators but without a pre-existing mandate. The operators' consensus in these countries is for a TDD pattern with uplink-downlink ratio between 1:3 and 1:4
- As a framework for regulators and operators to consider, GSMA suggests[6]: 1) defining a default national parameter set, 2) permitting operators to agree on localized arrangements and the use of alternative synchronization frame structures, and 3) allowing operators to update the agreed national TDD synchronization parameters.

[6] See GSMA's *5G TDD Synchronisation Guidelines and Recommendations for the Coexistence of TDD Networks in the 3.5 GHz Range.* https://www.gsma.com/spectrum/wp-content/uploads/2020/04/3.5-GHz-5G-TDD-Synchronisation.pdf

- Some countries have an alternate TDD configuration as well. The UK has a primary and alternate TDD pattern with a permissive and restrictive mask, respectively. Japan allows operators to use an alternate TDD pattern locally by changing some downlink slots to uplink.
- There are two predominant special slot configurations -> (Downlink: Guard Period: Uplink Symbols):
    - Without incumbents present in the band -> 10:2:2
    - With incumbents present in the band -> 6:4:4 or 4:6:4

Outcomes:

TWG4 found that the research done was useful to understand coexistence options used elsewhere. TWG4 was questioned as follows:

Question: Should TWG4 define a default and alternate frame configuration?
Answer: TWG4 did not reach a consensus on this issue, with most commenters preferring not to have a default configuration (See below).

Discussion:

- Those **in favor** of a default and alternate frame configuration said the following:
  - We should address this now. Waiting until an interference problem occurs is too late.
  - We should learn from other countries experience.
  - Up-front coordination of TDD configuration parameters will reduce the likelihood for service impairments and secure the value of C-Band and CBRS licenses.
  - Without alignment of TDD parameters, instances of interference could be widespread within the entirety of a licensed area, because operators often deploy network infrastructure in close proximity to competitors, who may be using adjacent TDD spectrum.
  - The identification and mitigation of interference between unsynchronized TDD networks will require different, possibly more rigorous, techniques than what operators conventionally apply to the resolution of interference in FDD bands. Adoption of a common default configuration could, therefore, reduce the effort and costs associated with performance and reliability engineering.

- Those **opposed to** a default and alternate frame configuration said the following:
  - Need flexibility to deploy TDD pattern that meets the business need in any given area.
  - CBRS Alliance Compliance certification of intra-CBRS TDD synchronization coexistence techniques is still being defined, due to be completed in Q4-2020
  - The operational impacts of CBRS operators adopting different TDD configuration (within CBRS band) and some not choosing/able to synchronize (within CBRS band), and procedures to handle such situations are unclear at this stage. They will become clearer as the deployments in CBRS band increase and mature over next several months.
  - Interference won't occur everywhere and a nationwide default is overly restrictive.
  - Licensees should be known before making such a decision
  - Cross-band interference might be able to be worked out using normal course of business techniques.

- Several commenters also **proposed a hybrid approach** which would provide some proactive measures to be better equipped if and when co- and adjacent-band interference becomes a prevalent issue that needs to be effectively managed (please refer to section 4e for specifics).

For further details, including the presentation supporting this section, please refer to Appendix D: Technical Details of SoW Item #4 Coexistence Options.

As a result of being unable to reach consensus, TWG4 took up the next SoW item (Coexistence management and coordination) with the following question: If no default TDD configuration, then how would a notification/coordination mechanism work? Please refer to Section 4e SOW item #5 below for details.

e. SOW Item #5 Coexistence Management and Coordination

In this chapter of the TWG4, we began with the context: if we don't have a default set of TDD synchronization parameters, then what should a CBRS / C-Band coordination or notification mechanism look like?

TWG4 debated multiple aspects of a coordination / notification mechanism extensively. However, we did not reach a consensus on answer(s) related to this question. The non-consensus items include the following: the timing for development of a coordination or notification mechanism, whether it made more sense to have a centralized vs. localized mechanism, whether or not a mechanism was required vs. normal course of business operations to solve cross-band interference problems, and the expected severity of cross-band interference problems.

Discussion:

Timing for development of a TDD coordination/notification mechanism?

- Those preferring to **develop coordination or notification mechanism after the C-Band auction** said the following:
    - The intra-C-Band coexistence mechanism should be worked out after the auction when the licensees and licensing are known. Following this, the inter-band coexistence should be worked out.
    - We've bounded the problem. Its scope could change based on the C-Band licensing and licensees. Therefore, it doesn't make sense to try to address the situation without knowing scope better. We may find that the interference problems are quite manageable.
    - The affected entities will work in good faith to find a solution; using TDD synchronization or otherwise.
    - It's too soon to develop a plan based on hypothetical circumstance. Wait until after the auction to do so. We should not speculate on who will be the C-Band licensees.
    - Other countries decisions are based upon intra-band considerations. CBRS Alliance Compliance certification of intra-CBRS TDD synchronization coexistence techniques is still being defined, due to be completed in Q4-2020
    - Part 96 regulations do not accord adjacent channel protections within CBRS and solutions are being evaluated by the industry.
    - Unlike other countries' regulators, the FCC has traditionally avoided technology mandates and it allows the licensees to determine how to implement their networks.

- Those preferring to **develop coordination or notification mechanism now** said the following:
    - While it is clear that we don't know all the players, we have worked out that interference can occur.
    - Global operators have already been dealing with TDD networks longer than we have and they agree that it is a problem but we cannot seem to. We should take their experience into account and solve this now. There is an interference problem with unsynchronized TDD and we should do something about it.
    - All parties who will be C-Band licensees are already present in the TWG4, so we don't need to wait until later to address TDD synchronization coordination.

Are normal course of business operations to solve cross-band interference problems sufficient?

- Comments asserting that **normal course of business operations <u>are not sufficient</u>**:
  - Lack of a coordination/notification mechanism could hurt the value of the spectrum. Operational predictability is worth the cost of some flexibility.
  - It will not be straightforward and will be labor-intensive to identify the lack of TDD synchronization as the cause of degradation. These interference problems will be inside of the license area boundaries and worse than current FDD license boundary area problems.
- Comments asserting that **normal course of business operations <u>are sufficient</u>**:
  - Cross-band interference mitigation is a natural extension of license boundaries coordination, which is done in the normal course of business.

As a result of the non-consensus, we don't have specific immediate-term recommendations on this topic.

Hybrid approaches

There were also some hybrid approaches discussed at the TWG4 9-18-2020 meeting. We discussed the following two proposals, but did not reach any agreement on them.

- Create a "passive/low touch" public database that could help quickly identify potential interference between TDD systems. This proposed database would contain potential interferer candidates and would require operators to register network devices in a generalized way to help determine root cause of co- or adjacent channel TDD interference. The solution could address the concern that operators often don't want to share information about their network infrastructure.
- Consider a list of "interference mitigation techniques" as part of a toolbox to use when interference issues become more prevalent. The toolset could include solutions such as
    - Remote interference management for NR, studied in 3GPP TR 38.866
    - Use of a PLMN scanner as a troubleshooting device which could help identify the source of the interfering signal (as discussed in TWG1 (FSS/ 3.7 GHz service coexistence)).

The following discussion points were brought up as part of the background formulating the above hybrid approach for coordinating and managing TDD interference and coexistence:

- The focus should be on what are the triggers for coordination. It should be an overarching framework to include how to qualify interference and how to identify the aggressor.
- We should also anticipate interference problems related to unsynchronized TDD systems will be inside of the license area boundaries (not just limited to the boundary areas). Therefore, the problem will be worse than current license boundary area problems.
- Triggers can be based on those used in the regular course of business. Affected parties exchange information as in a natural extension of license boundaries coordination. Triggers can be common industry Network KPIs (i.e. Throughput, Retainability, Accessibility, etc.). If cross-band interference is the root cause, the affected parties can work it out.
- Business as usual methods are the right way to deal with problems that might occur. Each operator has different KPIs. If their KPI(s) are exceeded, the operator should look into the problem on a site by site basis.
- Regarding the case-by-case resolution of interference problems without a TDD synchronization coordination mechanism: this is still labor-intensive and a better to have an up-front method.
- Regarding the database method of identifying the cause of interference, measurements are more accurate than radio propagation model but UEs are not tracked so a general "network presence" approach might be more practical.
- The best we can do at this point is to frame tools to mitigate interference from unsynchronized networks, including those from global operators.
- We don't have to mandate analysis, it shows that TDD sync is useful. In the future, we should follow global direction as other countries' networks utilization levels increase (and

interference would be more likely). Propose that the idea of tools be separated from the question of mandates.

f. SOW Item #6 Enforcement of Coexistence Practices

TWG4 did not take up this topic.

5. Appendix A: Statement of Work document

Below is the latest version of TWG4's statement of work (version 1.4).

1. Identify and Confirm Areas of Concern
    a. Absence of TDD synchronization between C-Band and CBRS operators and Intra-C-Band operators
    b. Impacts of Out of band emissions between CBRS and C-Band
    c. Receiver overload / co-location considerations
    d. Impact between non-3GPP operations in the CBRS band and C-Band Operations
    e. Potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions

2. Define Use Cases
    Define coexistence use cases

3. Quantifying the impacts of the areas of concern
Quantify the impacts of the areas of concern in the subsections below. Account for the following considerations during these efforts:
    • Use realistic equipment specifications and filter characteristics
    • Consider existing levels of intra-band interference,
    • Consider existing interference mitigation techniques

    a. Deterministic and statistical analysis of:
        i. Asynchronous TDD operation
        ii. Out of band emissions
        iii. Receiver overload and co-location
    b. Non-3GPP solutions:
        i. Determine the non-3GPP use cases being employed within CBRS and their usage across the band
        ii. Quantify the impact between non-3GPP use cases and 3GPP use cases and the probability of the impact over the next 3-5 years as 3GPP based solutions gather scale

4. Coexistence options
    a. Evaluate lessons learnt from global TDD deployments and their efficacy in the US
    b. Explore efficacy of other mitigation methods (e.g. CBRS/C-Band eco-systems, isolation and guard bands, etc.)
    c. Considerations over a policy decision on coexistence vs. establishing an industry-wide solution?

5. Coexistence management and coordination

a. Develop key information elements that need to be shared between operators in the C-Band and operators in the CBRS band.
b. Recommend actions to be taken by CBRS and C-band operators upon exchange of the information elements in 4.1
    i. Evaluate the role of the SAS in its current embodiment and if needed in an expanded scope
c. Determine the desired end-state of performance upon implementation of coexistence solutions and triggers to determine any deviation from desired end-state

6. Enforcement of coexistence practices
    a. Determine the process for re-alignment when deviations from the end state are detected
    b. Specify which operator the onus falls on for implementing remedial action as outlined in 4.2

7. Clarifications Needed
    [Insert as needed]

6. Appendix B: Technical Details of SoW Item 2 - Define Use Cases

a. Overall Approach

As part of the initial discussions during the first few TWG4 meetings, it was immediately recognized that this working group needed to document and logically qualify the exponential combinations of C-Band – CBRS Band co-existence Use Cases. To address this concern, the TWG4 team converged took a top-down approach of identifying Use Case Parameters that would be used to categorize and quantify the full set of Use Case Scenario combinations. To aid with this analysis and categorization, the team created a "Use Case Analysis Worksheet" (attached below) that includes the parameters and tabulated combinations and distillation of filtered Priority 1 Use Cases.

This appendix articulates the thought process and analysis performed by the TWG4 team in order to manage and distill the huge number of theoretical Use Case combinations (> 1.2 million) down to a manageable and practical number (<204). This level of intelligent filtering facilitates a more targeted and in depth analysis of the probability and performance impact of the mutually agreed primary use cases while providing a frameworks for guidance on other "less likely" or "corner" use cases.

b. Analysis Summary

In Summary, the Use Case Analysis quantified 5 out of 16 Priority 1 Parent Use Case "categories" of which there are 1,216,512 possible "Unfiltered" Priority 1 Use Case combinations. Appreciating this was clearly an unmanageable number of Use Case Scenarios for analysis, certain Use Case Parameter combinations were fixed to achieve a minimum filtered subset of Priority 1 Use Case Combinations narrowed down to 204.

Finally, the list of 204 filtered Priority 1 Use Case Combinations was tabulated in detail and further analyzed in a pivot table to help the TWG4 team to agree on focusing on the C-Band to CBRS Band 3GPP BS-BS analysis as a baseline for detailed interference simulation analysis. The following figure summarizes the breakdown of the 204 filtered Priority 1 Use Case Combinations based on Parent Use Case and Co-Location vs Separated categories:

Count of Priority	Column Labels								
	Co-located			Co-located Total	Separated			Separated Total	Grand Total
Parent Use Case	Rural	Suburban	Urban		Rural	Suburban	Urban		
C-Band/3GPP/BS to CBRS/3GPP/BS	4	4	4	**12**	4	4	4	**12**	24
C-Band/3GPP/BS to CBRS/Non-3GPP/BS	8	8	8	**24**	8	8	8	**24**	48
CBRS/3GPP/BS to C-Band/3GPP/BS	4	4	4	**12**	4	4	4	**12**	24
CBRS/3GPP/UE to C-Band/3GPP/UE	6	6	6	**18**	6	6	6	**18**	36
CBRS/Non-3GPP/UE to C-Band/3GPP/UI	12	12	12	**36**	12	12	12	**36**	72
Grand Total	**34**	**34**	**34**	**102**	**34**	**34**	**34**	**102**	**204**

c. Use Case Analysis Worksheet

The following attached XLS worksheet (**C-Band - CBRS Band Co-existence Use Case Matrix_1.4.xlsx**) contains the result of the joint TWG4 analysis of C-Band – CBRS Band co-existence Use Cases:

C-Band - CBRS Band Co-existence Use Cas

The following list summarizes the content contained within each respective tab in the attached XLS worksheet:

- **Revision Control** – Self-explanatory list of key tracked updates made to this XLS
- **Use Case Parameters** – Top-down listing of parameters to help categorize and quantify Use Case Scenario combinations
- **Parent Use Case Scenarios** – Listing and breakout of primary Use Case Scenarios for ranking Priority plus analysis table for quantifying Use Case Scenario Combinations with filtering strategy to reduce Priority 1 Use Cases into a Minimum Combination Subset of 204 filtered Priority 1 Use Cases
- **Parent Use Case Definitions** – Summary table to define the Parent "Umbrella" Use Case Scenarios
- **Parent Use Case Pivot** – Summary pivot table based on primary Use Case Scenarios listed as a table in the **Parent Use Case Scenarios** tab
- **Priority Use Cases** – Detailed table listing all 204 combinations of the filtered Priority Use Case combinations quantified from the **Parent Use Case Scenarios** tab
- **Priority Use Case Pivot** – Pivot table based on the tabulated data of 204 filtered Priority 1 Use Cases from the **Priority Use Cases** tab

d. Criteria Used and Thought Process

This section summarizes the criteria used and the thought process the TWG4 Team followed to distill the number of C-Band / CBRS Band Co-existence Use Case Scenarios down to a manageable and practical number.

In developing the attached Use Case Analysis Worksheet above, the TWG4 team started by defining an exhaustive list of Use Case Parameters grouped in a logical manner of Transmitter / Receiver Use Case Parameters plus Additional Use Case Scenario Parameters as detailed in the **Use Case Parameters** tab.

The Use Case Parameters were then tabulated and grouped into **Parent Use Case Scenarios** tab where the TWG4 team evaluated and ranked the Priority of each of the 16 qualified Parent Use Case Scenarios from 1 – High to 4 – Low. This was further summarized on the **Parent Use Case**

Definitions and **Parent Use Case Pivot** tabs where 5 Priority 1 Parent Use Case Scenarios were identified.

At this point, the next level of analyzing the number of Use Case Parameter Combinations was performed on the 5 Priority 1 Parent Use Case Scenarios on the lower portion of the **Parent Use Case Scenarios** tab. As can be seen, when expanding the sub-category parameters, the additional combinations skyrocket to 100s of thousands until the total number possible "Unfiltered" Priority 1 Use Case combinations was quantified as 1,216,512. Clearly, some intelligent filtering needed to be done to make this a more manageable number.

In order to reduce the number of Priority 1 Use Case Combinations, each Use Case Parameter was looked at and determined if could be fixed or limited to the most relevant and applicable setting. This determination was made based on guidance and feedback from the TWG4 group but ultimately was the decision made by the author of the analysis worksheet. The rows highlighted in yellow in the lower portion of the **Parent Use Case Scenarios** tab highlight the filtering decisions made for each Use Case Parameter, resulting in a significant reduction down to only 204 Priority Use Case combinations.

The 204 Priority Use Case combinations were explicitly tabulated in the **Priority Use Cases** tab so they could be analyzed in the compiled **Priority Use Case Pivot** tab. At this point, the TWG4 Team agreed that the reduction of C-Band / CBRS Band Co-existence Use Case Scenarios down to a manageable and practical number had been achieved.

Based on the list of 204 Priority Use Cases and the preliminary Analysis Factors summarized in the **Use Case Parameters** tab, the TWG4 Team moved onto the detailed interference simulation analysis. The analyses in this report, shows interference analysis between 3GPP base stations in the CBRS and C-Bands

7. Appendix C: Technical Details of SoW Item 3 - Quantifying the impacts of the areas of concern

Most of TWG4's work to quantify interference performance impacts focused on examining the effect of varying degrees of TDD Synchronization between the networks under study. The TWG4 concluded that the absence of synchronization could mutually degrade the performance of both CBRS and C-Band networks to varying degrees.

In the absence of information on the characteristics of commercial C-Band equipment, TWG4 opted for providing a range of specifications to help provide some sensitivity analysis on how a change in specification values might have varying degrees of impact to co-existence performance.

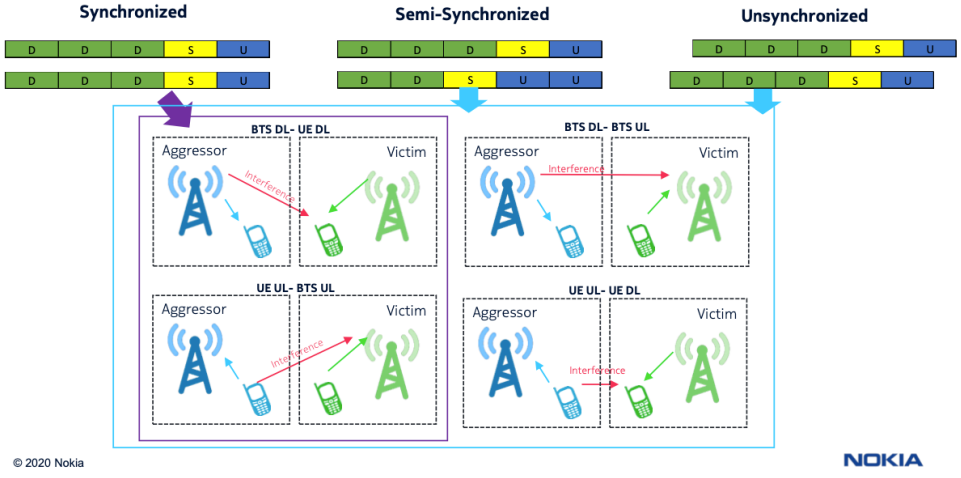
In order to achieve synchronized operation, the following needs to be implemented on all Base Stations (BSs) that may interfere with each other:

- Common reference phase clock: For the start of frame.
- Configuring compatible frame structures: Length of frame, TDD ratio in order to align uplink/downlink switching points.

In case two TDD networks are unsynchronized and in adjacent bands, there are four possible scenarios of interference:

- BS to BS interference: BS downlink to BS uplink
- UE to UE interference: UE uplink to UE downlink
- BS to UE interference: BS downlink to UE downlink
- UE to BS interference: UE uplink to BS uplink

The TWG4 static analysis reports on BS to BS interference.



The most critical scenario in case of unsynchronized networks is BS to BS interference and UE to UE interference. The interference impact was quantified by doing static and dynamic simulations and the following sections will cover the methodology and results from the models.

a. Static Model:

In the static model, BS to BS interference was analyzed as it is relatively static and affects a large number of users. As the model is static, the analysis was done to calculate the isolation requirements using path loss assumptions. The isolation requirements were calculated by considering the BS output power, ACLR, ACS, and ACIR which were calculated to values used as per 3GPP specifications. The isolation value was calculated to consider the impact of both transmitter and receiver and factor dominated was used in the calculations. There was additional isolation factor added to the final values to compensate for the power control and beamforming.

Different propagation models were used to quantify the isolation requirements in different propagation environments. The models used in the static analysis are

- Winner 2 Urban nLos
- Winner 2 Sub-Urban nLos
- Winner 2 rural nLos
- Winner 2 Urban Los
- Winner 2 Sub-Urban Los
- Winner 2 rural Los
- Cost 231 Urban
- Cost 231 Sub-Urban

The analysis was done to calculate the impact of C-band on CBRS and also CBRS on C-band when the two network with be un-synchronized. The isolation requirement calculated in the analysis is based on 3GPP spec values and FCC operational limits, the isolation values can further be impacted by the antenna characteristics, antenna orientations, additional filtering on the BS side and that is why in the analysis the range was calculated to see the impact of different values on the isolation requirements.

Base station and user terminal parameters and isolation analysis for the C-band and CBRS TDD system simulated are shown in the following table:

		Case 1 Macro C-band to Macro CBRS				Case 2 Macro CBRS to Macro C-Band			
		Interference - Source (TX)	Interfered - Destination (RX)			Interference - Source (TX)	Interfered - Destination (RX)		
	Technolgy	C-band	CBRS	CBRS	CBRS	CBRS	C-band	C-band	C-band
	Air Inerface	NR	LTE	LTE	LTE	LTE	NR	NR	NR
Ghz	Centre Frequency	3.75	3.69	3.67	3.65	3.69	3.71	3.75	3.8
m	BS Height	30	30	30	30	30	30	30	30
m	UE Height	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
MHz	Bandwidth	20	20	20	20	20	20	20	20
dBm/MHz	BS PSD	62	37	37	37	37	62	62	62
dBm	TX EIRP	75	50	50	50	50	75	75	75
dBm / Mhz	OOBE	-13	-13	-13	-13	-13	-25	-25	-40
dBi	Antenna Gain	24	11	11	11	24	24	24	24
dB	Noise Figure	6	6	6	6	6	6	6	6
dBm	Noise Floor	-94.82	-94.82	-94.82	-94.82	-94.82	-94.82	-94.82	-94.82
dBm	3GPP P_REFSENSE	-96.5	-96.5	-96.5	-96.5	-96.5	-96.5	-96.5	-96.5
dBm	P_REFSENSE_Wanted Signal	-90.50	-90.50	-90.50	-90.50	-90.50	-90.50	-90.50	-90.50
dBm	3GPP Blocking		-38	-38	-38		-38	-38	-38
dB	ACLR		51	51	51		38	38	53
dB	ACS		53	53	53		53	53	53
dB	ACIR		49	49	49		38	38	50
	Equivalent channel power		26	26	26		12	12	0
dBm	Interference Threshold		-108	-108	-108		-121	-121	-121
dB	Required Isolation		134	134	134		133	133	121
dB	Beamforming adjustment		20	20	20		20	20	20
dB	Power reduction adjustment		0	0	0		0	0	0
dB	Adjusted Isolation		114	114	114		113	113	101
m	Winner 2 Urban nLos		124	125	125		115	114	52
m	Cost 231 Urban		95	96	96		88	87	39
m	Winner 2 Sub-Urban nLos		151	152	153		140	139	63
m	Cost 231 Sub-Urban		430	432	435		396	392	178

Summary of analysis of BS-BS interference:

This section discusses the analysis summary and the following attached simulation spreadsheet includes the detailed model used for the analysis:

Simulation Parameters_Rev1.8

The chart below shows an example for one of the use case of C-band to CBRS impact in non-line of sight urban environment. In this case, the isolation ranges with beamforming, power adjustment as well as without the adjustment are shown.

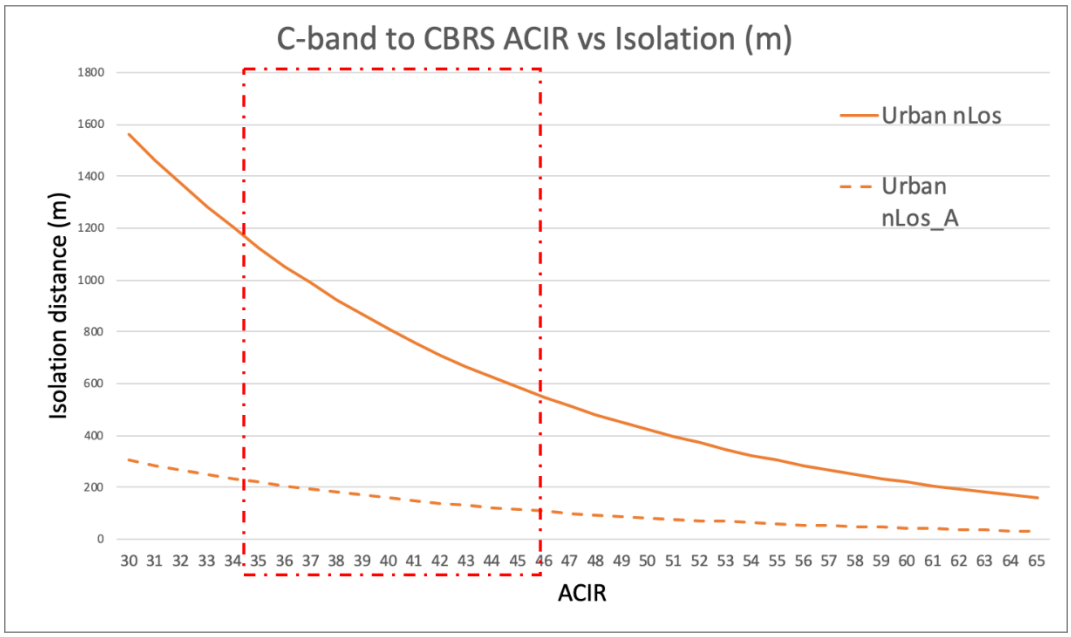


Figure 2 Deterministic analysis- worst case C-Band base station to CBRS base station interference

As seen in the chart above the isolation distance with beamforming/power adjustment will range from 250m to 100m for the ACIR values of 35-45 dB.

Key Results Summary:

- The primary area of concern was the BS-BS interference, and the findings from the deterministic analysis was that the interference threshold, characterized by an ACIR target range, as published in the 3GPP specification[7] was exceeded when the unsynchronized adjacent networks base stations were nearby to each other.
- The analysis found that a separation distance of 100 – 250 m would be required in order to avoid exceeding the interference threshold, see chart below. This outcome (as seen as "Urban NLos_A in the chart) is based upon the use of a 25 dB interference reduction to account for beamforming efficiency

Caveats

There were comments from the group regarding the applicability of some aspects of the analysis, including the following:

- The 3GPP blocking spec used in our analysis is meant for the certification of equipment, and is not related to network performance in the field. A capacity simulation is in order, calculating throughput reductions.
- The 6 dB interference spec is an equipment testing spec, and does not mean the receiver will get desensitized. This is a corner case and the use of this value doesn't indicate how frequently this situation could occur. In contrast, a standardized 3GPP method that quantifies how often unacceptable degradation would occur in a given scenario. Note that the 3GPP method assumes a synchronized TDD.
- Others commented that the current set of parameter values are suitable for worst-case.
- There was discussion about the lack of realistic equipment specifications and the applicability of using FCC limits for e.g. out of band emissions (OOBE) and maximum effective isotropic radiated power (EIRP), since we expect that actual equipment will perform better than FCC limits and the likely use of lower power in urban areas. The interference impacts due to unsynchronized aspects are also applicable to within the CBRS band.

[7] See 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; NR; Base Station (BS) radio transmission and reception, 3GPP TS 38.104.
https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3202

b. Dynamic Model:

See Section 4. C. ii. for description of the Dynamic Simulation results.

The related presentation is attached below:

Nokia
CBAND-CBRS_v6.7 D

c. Measurements in an unsynchronized TDD CBRS Network.

See Section 4. C. iii. for a description of the measurements in an unsynchronized TDD CBRS Network.

The related presentation is attached below.

Asymmetric CBRS
LTE TDD configuratio

d. Impact of relative levels of network loading on CBRS / C-Band networks that are fully synchronized

See Section 4. C. iv. for a description of Impact of relative levels of network loading on CBRS / C-Band networks that are fully synchronized.

The related presentation is attached below.

CBRS coexistence
analysis twg4 revE.p

8. Appendix D: Technical Details of SoW Item 4 - Coexistence Options

TWG4 examined coexistence options, including a survey of what is happening globally in the mid-band TDD networks (2, 3, and 4 GHz bands). We also looked at various global regulatory and operator's intra-band coexistence methods, see below

The following summarizes the two presentations on the topic:

- Licensing was a mix of allocation of spectrum to the operators and auctioning of spectrum.
- The use of guard bands was rare, except for one 4G case.
- In 5G networks, coordination among operators is the method for deciding TDD parameters. The Chinese regulator was involved in organizing negotiations. In 4G networks, there was more regulator involvement including three mandating a set of TDD parameters.
- In many countries that we analyzed, with or without a regulatory mandate, operators are collaborating in the choice of specific TDD configuration parameters, to be applied in-common among all networks using adjacent unpaired spectrum allocations.
    - Japan's ministry of communications guidelines recommends that operators support the industry-consensus TDD parameters.
    - China's MIIT recommends synchronization for adjacent TDD systems, and requests that operators negotiate with one another to identify specify synchronization schemes
    - Operators in several European countries have selected a preferred TDD pattern, with the encouragement of local regulators but without a pre-existing mandate. The operators' consensus in these countries is for a TDD pattern with uplink-downlink ratio between 1:3 and 1:4
- As a framework for regulators and operators to consider, GSMA suggests[8]: 1) defining a default national parameter set, 2) permitting operators to agree on localized arrangements and the use of alternative synchronization frame structures, and 3) allowing operators to update the agreed national TDD synchronization parameters.
- Some countries have an alternate TDD configuration as well. The UK has a primary and alternate TDD pattern with a permissive and restrictive mask, respectively. Japan allows operators to use an alternate TDD pattern locally by changing some downlink slots to uplink.

[8] See GSMA's *5G TDD Synchronisation Guidelines and Recommendations for the Coexistence of TDD Networks in the 3.5 GHz Range.* https://www.gsma.com/spectrum/wp-content/uploads/2020/04/3.5-GHz-5G-TDD-Synchronisation.pdf

- There are two predominant special slot configurations -> (Downlink: Guard Period: Uplink Symbols):
    - Without incumbents present in the band -> 10:2:2
    - With incumbents present in the band -> 6:4:4 or 4:6:4

The following are further findings of TWG4's research on various countries' 5G mid-band TDD coexistence efforts.

Country	Allocated Band	Licenses	Guard Bands	TDD Coordination
Japan	3600 – 4100 MHz 4500-4600 MHz	3600 – 4100 MHz split between 4 operators	Not used	Regulator draft guidelines proposed that operators agree on TDD synchronized operation such as transmission time and frame structure
China	3400 – 3600 MHz, awarded to 3 MNOs, June 2019 4800 – 4900 MHz, awarded to 3 MNOs, June 2019 4900 – 4960 MHz, awarded to China Broadcasting Network, June 2019	See Allocated Bands	Not used	Regulator organizing MNO/stakeholders to negotiate a single TDD scheme for 3500 MHz band. Regulator rules that interference due to out-of-sync operations must be coordinated
Italy	3600-3800 MHz, June 2017	unknown	Not used	Operators will coordinate to decide synchronization framework. Post – auction, Regulator set up working groups of licensees.
Germany	3400 – 3700 MHz, auction June 2019 3700 – 3800 MHz, applications Nov 2019, private use 'innovative 5G solutions'	TBD	Not used	Operators to coordinate agreeable solution
USA	3550 – 3700 MHz	Multiple, 10 MHz each.	Not used	Proposed local coordination via *Connected Sets*

The following countries have a national preferred frame structure (see table below for details of the choice of TDD pattern):

- Japan, China, Malaysia, South Korea, UK, Ireland, Spain, Germany, France, Italy, Austria, Norway, Denmark, Sweden, Switzerland, Belgium.

#	Country	Pattern
1	Norway	DDDSU
2	Denmark	DDDSU
3	Sweden	DDDSU
4	Germany	DDDSU
5	Switzerland	DDDSU
6	Belgium	DDDSU
7	Luxembourg	DDDSU
8	South Korea	DDDSU
9	France	DDDDDDDSUU
10	Italy	DDDDDDDSUU
11	Austria	DDDDDDDSUU
12	Ireland	DDDDDDDSUU
13	Japan	DDDDDDDSUU
14	China (excluding Taiwan, HK, Macau)	DDDSUDDSUU
15	United Kingdom	DDDSUUDDDD

Source: https://i0.wp.com/www.gsma.com/spectrum/wp-content/uploads/2020/04/5G-TDD-Synch-map.png?ssl=1

Of the countries listed above, the following also offer an alternative to enable some degree of flexibility:

- Japan: Local 5G operators can have an alternate pattern where DL slots can be changed to UL.
- UK and Ireland: Adopted alternate ‘semi-synchronized’ frame structure with a ‘restrictive’ (more conservative) emissions mask for its base-stations.

The following GSMA recommendations follow global usage of the TDD patterns shown in the above table:

Recommended parameters for when there are no incumbents in the band, (only 5G NR networks present)[9]

- Preferred frame structure: DDDSU
- Subcarrier Spacing (SCS): 30 kHz
- Cyclic prefix = Normal (corresponding to 3GPP numerology 1).
- Special slot "S" format is 10:2:2 (10 Downlinks, a 2 Guard Periods and 2 Uplinks, symbol periods)

Recommended parameters for the best compromise for performance where coexistence with incumbent LTE systems is required.[10]

- 5G NR networks use on of the following patterns
  - DDDSUUDDDD or
  - DDDDDDDSUU (with a 3ms shift)
- Subcarrier Spacing (SCS): 30 kHz
- Special slot "S" format is 6:4:4 (6 Downlinks, 4 Guard Periods and 4 Uplinks, symbol periods)
- Normal cyclic prefix

The related presentations are attached below.

Nokia C-Band -CBRS TDD synch.pd

TDD coexistence globally v1 for 7-31-

TDD coexistence global analysis for 9

[9] GSMA Recommendation #3, Case a) Incumbent systems are not present in the band [in adjacent band in CBRS case]. https://www.gsma.com/spectrum/wp-content/uploads/2020/04/3.5-GHz-5G-TDD-Synchronisation.pdf

[10] GSMA Recommendation #3, Case b) when incumbent systems are present in the band [in adjacent band in CBRS case]. Provide[s] the best compromise for performance where coexistence with incumbent LTE systems is required.
https://www.gsma.com/spectrum/wp-content/uploads/2020/04/3.5-GHz-5G-TDD-Synchronisation.pdf

9. Appendix E: TWG4 Meeting Minutes

This appendix contains the meeting minutes from the TWG4 meetings.

a. 6-5-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 6/5/2020, 1:30pm, Eastern Time

ACTIONS

- Members should volunteer to carry out required tasks for the working group. See "Volunteers for analysis" section below
- Existing Volunteers can begin work on their duties.
- Co-chairs to provide clarification on in/out of scope status of several items listed below in "Proposed additions to SoW Areas of concern" section. The items are in [square brackets]
- Co-Chairs: schedule next meeting Friday at 1:30 – 2:30 pm, Eastern Time.

REPRESENTED ON THE CALL
AT&T
CCA
Charter
Comcast
Commscope
CTIA
Ericsson
Federated Wireless
NCTA
Nokia
Qualcomm
Samsung
T-Mobile
US Cellular
Verizon
Viaero
Windstream
WISPA

Report of Technical Working Group #4 (C-Band / CBRS Coexistence)
Report Date: October 06, 2020

PUBLISHED AGENDA:

- Roll call
- FCC Quiet Period Statement
- Agenda review and co-chair comments
- Administrative:
    - e-mail management (Google Groups)
    - Document review & markup
- Statement of Work Review and comments
    - Agreement on Areas of concern
    - Comments / suggestions for modifications to SoW
- Overview of the coexistence issues, Navin from Nokia.
- Next Steps
    - further comments
    - volunteers for performing analysis
- Any other business

ATTACHMENTS TO THE PUBLISHED AGENDA:

- *C-Band TWG4 SoW version 1.0.docx*

NOTES

- Email Management. Our distribution list e-mail address for the working group is FCC-C-Band-TWG4@googlegroups.com
    - When you send an e-mail to this address, it automatically prefixes the e-mail subject with [FCC C-Band TWG4]
    - The e-mail footer has a link to view all the communications/members of the group on a web interface. It also has an unsubscribe link.
- Document review method. Document review and markup will be via e-mail unless unsustainable or we find a better way
- Review of SoW "Areas of Concern". General agreement on the existing "Areas of concern" items on the SoW v1.0. We will clarify certain language in the SoW, as requested by members.
- Proposed additions to SoW Areas of concern" Members raised possibility of adding additional "areas of concern" for this group to study.
  Co-chairs to take this under advisement and concern to what extent seeking FCC advice is relevant. Co-chairs to consider the various comments from the group on these prospective "areas of concern":
    I. [Potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions]
    II. [Interaction and potential disruption between C-Band service and CBRS band's incumbents – esp. the FSS ES]

III. [Impact of CBRS band radar systems to C-Band Operations]

The co-chairs will revert with clarity on which of the three [square bracketed] sub-items will be within the scope of this TWG

Beyond the assertions about what is in/out of scope of the group, Masoud noted that the CBRS SAS does not monitor inbound interference to the incumbent tier operations.

- Volunteers for analysis. We need volunteers to perform portions of the work for this TWG. Please e-mail your willingness to the co-chairs: peter.tenerelli@verizon.com (Pete Tenerelli) and PJ.Jayawardene@charter.com (PJ Jayawardene). The volunteers listed below will solicit feedback/input from the members of the TWG wherever possible in performing their analyses.

Here are the slots that need immediate attention:

- SoW Section 2 Define coexistence use cases
  - Notes: Cameron proposes to start with a matrix of cases where interaction could occur between the C-Band and CBRS services.
  - Volunteers: Cameron Gillis c.gillis@sea.samsung.com and Shahzad Bashir shahzad.bashir6@t-mobile.com
- SoW section 3. Quantifying the impacts of the areas of concern.
  First steps
  - Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc.
  - Identify existing mechanisms creating intra-band interference and governing parameters
  - Identify existing interference mitigation techniques and governing parameters
  - Volunteers: Navin Hathiramani navin.hathiramani@nokia.com, Ramneek Bali Ramneek.Bali@charter.com

  Second steps
  - Using the first steps above, perform deterministic and statistical analyses for the agreed-upon use cases in the areas of:
    - Asynchronous TDD operation. Volunteers: Ramneek Bali (Ramneek.Bali@charter.com) We need additional volunteer(s)
    - Out of band emissions. Volunteers: Ramneek Bali (Ramneek.Bali@charter.com) We need additional volunteer(s)
    - Receiver overload and co-location. Volunteers: Ramneek Bali (Ramneek.Bali@charter.com) We need additional volunteer(s)
    - Non-3GPP solutions. Volunteers: TBD

- SoW section 4a. Evaluate lessons learnt from global TDD deployments and their efficacy in the US. Volunteers: TBD

END.

Sincerely,
TWG-4 (3.7 GHz service / CBRS coexistence) Co-chairs:
PJ.Jayawardene@charter.com (PJ Jayawardene).
peter.tenerelli@verizon.com (Pete Tenerelli)

b. 6-12-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 6/12/2020, 1:30pm, Eastern Time

ACTIONS

- Members should comment on the Draft Use Cases document circulated by Cameron Gillis
- Request members volunteer to carry out required tasks for the working group. See Table below for volunteer slots highlighted in yellow
- Existing Volunteers can continue working in their respective areas
- Next meeting Friday June 19th 1:30 – 2:30 pm, Eastern Time.

REPRESENTED ON THE CALL

AT&T
Charter
Comcast
Commscope
CTIA
Ericsson
Federated Wireless
GCI
Google
NCTA
Nokia
T-Mobile
US Cellular
Verizon
Windstream
WISPA

Report of Technical Working Group #4 (C-Band / CBRS Coexistence)
Report Date: October 06, 2020

PUBLISHED AGENDA:

- Roll call
- FCC Quiet Period Statement
- Agenda review and co-chair comments
- Progress recap
  - Scope / SoW agreement
  - Scope / SoW changes since last week. Clarifications, proposed additions.
- Open Actions from last week
  - Volunteers. We need volunteers to perform some of the work.
- Presentation on C-Band / CBRS coexistence considerations.
- Review of Use case definitions
- Next Steps
  - Volunteers for performing analysis
  - Choosing next meeting interval
- Any other business

ATTACHMENTS:

- *Nokia C-Band -CBRS TDD synch.pdf*
- *C-Band TWG4 SoW version 1.4.docx*

MEETING NOTES

- **TWG Scope.** Co-Chairs presented disposition of the proposed scope additions, listed below. The current version of the Statement of Work is version 1.4 (attached).
  - **Include** *Potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions*
  - **Exclude** *Interaction and potential disruption between C-Band service and CBRS band's incumbents – esp. the FSS ES*
  - **Exclude** *Impact of CBRS band radar systems to C-Band Operations*
- Navin Hathiramani gave a presentation on CBRS / C-Band considerations and prevailing circumstances. See attached.
- Google, Federated Wireless and Commscope to work on the potential impacts from C-Band to the CBRS' ESC system
- Subsequent discussion was that most CBRS deployments today are non-3GPP and that sync methods within CBRS are under study by the WInnForum.
- Cameron Gillis made a brief introduction the team's work on to the Coexistence Use Cases task. Cameron has circulated the document for comments via email. Shahzad Bashir and Andy Clegg collaborated on the development of this deliverable.
- Ongoing and near-term work efforts. See table below.

Item	Work area	Personnel	Pre-cursor item
1	Define coexistence use cases	Cameron Gillis c.gillis@sea.samsung.com Shahzad Bashir shahzad.bashir6@t-mobile.com	-
2	• Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc. • Identify existing mechanisms creating intra-band interference and governing parameters • Identify existing interference mitigation techniques and governing parameters	Ramneek Bali Ramneek.Bali@charter.com Need additional volunteers	-
3	Evaluate lessons learnt from global TDD deployments and their efficacy in the US	Need volunteers	-
4	Perform deterministic and statistical analyses for the agreed-upon use cases in the areas of:	-	-
4a	Asynchronous TDD operation	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4b	Out of band emissions	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4c	Receiver overload and co-location	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4d	Non-3GPP solutions	Need volunteers	1, 2
5	Examine potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions	Mark Gibson mgibson@comsearch.com Masoud Olfat masoud.olfat@federatedwireless.com Andy Clegg aclegg@google.com	

END.
Sincerely,
TWG-4 (3.7 GHz service / CBRS coexistence) Co-chairs:
PJ.Jayawardene@charter.com (PJ Jayawardene).
peter.tenerelli@verizon.com (Pete Tenerelli)
FCC-C-Band-TWG4@googlegroups.com (e-mail list)

c. 6-19-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 6/19/2020, 1:30pm, Eastern Time

ACTIONS

- Members should comment on the revised use cases document circulated by Cameron Gillis. We want to identify the high priority use cases by next week.
- Google/Federated/WISPA to provide details of TDD sync between 3GPP and non-3GPP deployments during next meeting.
- Request members volunteer to carry out required tasks for the working group. See Table below for volunteer slots highlighted in yellow
- Existing Volunteers can continue working in their respective areas
- Next meeting Friday June 26th 1:30 – 2:30 pm, Eastern Time. Meeting cancelled on July 3rd 2020.

TODAY'S MEETING

- **Use Cases**. Cameron Gillis presented the use cases in more detail. The team discussed them. Members to further comment by e-mail.
- **Use cases discussion.** We discussed the following items (See e-mails from Cameron Gillis for full details)
  - Consider beam forming and power based classification in the radio categories
  - Consider single and aggregate interference impacts
  - Include revision tracking on the use case spreadsheet
- **Non-3GPP deployments**. Andy said that more than 50% of current CBRS deployments are non-3GPP. Masoud said that some of these non-3GPP deployments have the possibility of synchronizing with 3GPP TDD systems. Potentially, this represents a partial solution. Additional work being done by the SAS administrators in WiNN-F on developing a mechanism whereby TDD information from non-3GPP air interfaces can be exchanged. More details to follow next week
- **Protection of CBRS ESC's**. Impact to ESC from C-Band operation studies being conducted in WiNN-F, and SAS administrators to report back to TWG 4 on progress and results. The team further decided that ESC protections would be analyzed separately from the use cases
- **Topics for next meeting**
  - Lock down use case priority list
  - Information exchange on non-3GPP solution that has the ability to sync with LTE/NR

REPRESENTED ON THE CALL

CCA	Charter	Comcast	Commscope
CTIA	Ericsson	Federated Wireless	Google
Nokia	Qualcomm	Samsung	T-Mobile
US Cellular	Verizon	Windstream	WISPA

PUBLISHED AGENDA:

- Roll call
- FCC Quiet Period Statement
- Agenda review and co-chair comments
- Progress recap
  - Cameron Gillis presented draft use case definitions last week.
- Open Actions from last week
  - Volunteers. We need volunteers to perform some of the work.

Item	Work area	Personnel	Pre-cursor item
1	Define coexistence use cases	Cameron Gillis c.gillis@sea.samsung.com Shahzad Bashir shahzad.bashir6@t-mobile.com	-
2	• Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc • Identify existing mechanisms creating intra-band interference and governing parameters • Identify existing interference mitigation techniques and governing parameters	Ramneek Bali Ramneek.Bali@charter.com Need additional volunteers	-
3	Evaluate lessons learnt from global TDD deployments and their efficacy in the US	Need volunteers	-
4	Perform deterministic and statistical analyses for the agreed-upon use cases in the areas of:	-	-

Item	Work area	Personnel	Pre-cursor item
4a	Asynchronous TDD operation	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4b	Out of band emissions	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4c	Receiver overload and co-location	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4d	Non-3GPP solutions	Need volunteers	1, 2
5	Examine potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions	Mark Gibson mgibson@comsearch.com Masoud Olfat masoud.olfat@federatedwireless.com Andy Clegg aclegg@google.com	

END.
Sincerely,
TWG-4 (3.7 GHz service / CBRS coexistence) Co-chairs:
PJ.Jayawardene@charter.com (PJ Jayawardene).
peter.tenerelli@verizon.com (Pete Tenerelli)
FCC-C-Band-TWG4@googlegroups.com (e-mail list)

d. 6-26-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 6/26/2020, 1:30pm, Eastern Time

ACTIONS

- **Masoud** to send e-mail update on non-3GPP access solution that can achieve TDD sync with LTE/NR. We expect this will partially address the many non-3GPP technology deployments currently in the CBRS band. To be used for further group discussion.
- **Cameron** to send updated use case list with the expanded pivot table showing the permutations within the high-priority use cases
- **PJ and Pete** to discuss and provide distilled list of use cases for the group's review, we will then lock down the list of permutations for analysis. Discussion to be done over email in lieu of the time off around the 4th of July holiday
- Requesting **members** to volunteer to carry out required tasks for the working group. See Table below for volunteer slots highlighted in yellow
- **Existing Volunteers** can continue working in their respective areas
- **ALL**: Next meeting Friday July 10th 1:30 – 2:30 pm, Eastern Time. Meeting cancelled on July 3rd 2020.

TODAY'S MEETING

- **Timeline for TWG4.** Update from co-chairs: We will need to have our deliverables locked down and submitted to FCC in September. Pete and PJ will provide a timeline during the course of next week.
- **Use Cases**. Cameron Gillis led discussion of use cases in more detail. We agreed on 5 high-priority use cases, and to start with the analysis on 1 permutation (minimum) per use case.
  We discussed that some of the multitude of possible use case combinations will be reduced by the nature of the use case. For example, certain environment types will use only one type of antenna.
- **Topics for next meeting**
  - Use of TDD sync between 3GPP & non-3GPP technologies
  - TWG timelines

REPRESENTED ON THE CALL

CCA	Charter	Commscope	CTIA
Ericsson	Federated Wireless	Google	NCTA
Nokia	Samsung	T-Mobile	US Cellular
Verizon	Windstream	WISPA	

PUBLISHED AGENDA:

- Roll call
- FCC Quiet Period Statement
- Agenda review and co-chair comments
- Progress recap
  - Last week: Review / discussion of Use Case definitions / priority
  - Last-week: Brief discussion of non-3GPP prevalence in CBRS band & TDD sync possibilities
  - Last-week: Brief discussion of CBRS ESC protection analysis in Winnforum
- Open Actions from last week
  - Volunteers. We need volunteers to perform some of the work.
- TODAY'S MEETING
  - Lock down use case priority list
  - Information exchange on non-3GPP solution that has the ability to sync with LTE/NR
- Next Steps
  - Volunteers for performing analysis
  - Next topics for discussion
- Any other business

Notes:

- Current SoW version is version 1.4
  -

VOLUNTEER TABLE:

Item	Work area	Personnel	Pre-cursor item
1	Define coexistence use cases	Cameron Gillis c.gillis@sea.samsung.com Shahzad Bashir shahzad.bashir6@t-mobile.com	-

Item	Work area	Personnel	Pre-cursor item
2	• Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc • Identify existing mechanisms creating intra-band interference and governing parameters • Identify existing interference mitigation techniques and governing parameters	Ramneek Bali Ramneek.Bali@charter.com Need additional volunteers	-
3	Evaluate lessons learnt from global TDD deployments and their efficacy in the US	Need volunteers	-
4	Perform deterministic and statistical analyses for the agreed-upon use cases in the areas of:	-	-
4a	Asynchronous TDD operation	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4b	Out of band emissions	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4c	Receiver overload and co-location	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4d	Non-3GPP solutions	Need volunteers	1, 2
5	Examine potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions	Mark Gibson mgibson@comsearch.com Masoud Olfat masoud.olfat@federatedwireless.com Andy Clegg aclegg@google.com	

END.
Sincerely,
TWG-4 (3.7 GHz service / CBRS coexistence) Co-chairs:
PJ.Jayawardene@charter.com (PJ Jayawardene).
peter.tenerelli@verizon.com (Pete Tenerelli)
FCC-C-Band-TWG4@googlegroups.com (e-mail list)

e. 7-10-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 7/10/2020, 1:30pm, Eastern Time

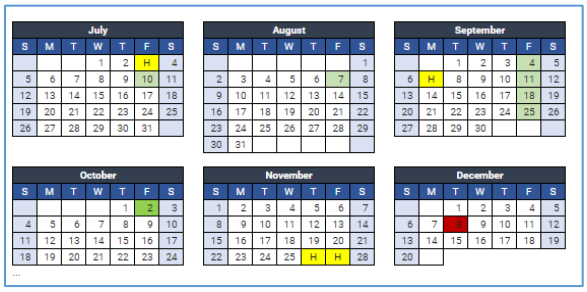
ACTIONS

- **Ramneek, Masoud, Ariful, and Raj** to recommend parameters for the group's consideration. Reference: volunteer table below: Item 2 *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc*
- Requesting **members** to volunteer to carry out required tasks for the working group. See Table below for volunteer slots highlighted in yellow
- **Existing Volunteers** can continue working in their respective areas
- **ALL**: Next meeting Friday July 17th 1:30 – 2:30 pm, Eastern Time.

TODAY'S MEETING

- **Schedule for Completion of SoW.** We discussed the large volume of work in the Working Group's Statement of Work and the need for volunteers. We reviewed a schedule working backwards from a Oct 2nd completion date:

Date	Milestone
10-Jul	Lock down list of use cases
7-Aug	SOW item 3 [Quantifying the impacts of the areas of concern] complete
28-Aug	SOW item 4 [Coexistence options] complete
4-Sep	SOW item 5 [Coexistence management and coordination] complete
11-Sep	SOW item 6 [enforcement of coexistence] complete
18-Sep	Recommendations finalized and drafted
25-Sep	Final Review of recommendations
2-Oct	TWG Recommendations submitted to OET
8-Dec	C-Band auction



Discussion:

- We observed that the 5 high priority use cases still have 200+ permutations, an impractical task given the time.
- To compress the scope, we proposed to analyze a subset of the use cases as illustrative examples and take them through the remaining SoW milestone. No objections.
- Ramneek, Masoud, Ariful, and Raj to recommend parameters for the group's consideration.

- **TDD Sync with Non-3GPP solutions.** Masoud gave a presentation on this topic. Presentation attached.

Discussion:

- Reviewed proposed methods of TDD alignment that a SAS could use to specify to a group of CBSDs in a *connected set*. In some cases, a CBSD could opt out from the TDD alignment method communicated by the SAS (e.g. indoor deployments)
- Reviewed CBRS TDD Uplink/Downlink configurations
- Pre-requisite for non-3GPP solutions to TDD sync is to have the ability to modify the frame structure. Currently no provision for SAS to apply a TDD sync for non-3GPP CBSDs, but possible path forward exists.
- Cambium (for fixed wireless) is the biggest non-3GPP solution for Federated Wireless SAS, (pending comments from other SAS providers if the statement holds true for their respective solutions)
- Process to getting non-3GPP sync:
    - Feasibility study. For Cambium done. For WiMAX, in progress. Other non-3GPP, unknown.
    - Protocol development. Via CBRS Alliance Protocol and/or new Winnforum protocol
    - Requires capability of non-3GPP operators and manufacturers to adjust TDD config. Dynamically. Discussion ongoing.
    - Reviewing possibility and requirement of opt-out by some CBSDs

- **New Volunteers.**
    - Thank you to our new volunteers or those taking on additional responsibilities: Masoud, Ariful, Raj.

- **Topics for next meeting**
    - Review findings / recommendations of the Item 2 from the volunteer table *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc.*

REPRESENTED ON THE CALL

CableLabs	CCA	Charter	Commscope
CTIA	Ericsson	Federated Wireless	Midco
NCTA	Nokia	Qualcomm	Samsung
T-Mobile	US Cellular	Verizon	Windstream
WISPA			

Notes:
- Current SoW version is version 1.4

VOLUNTEER TABLE:

Item	Work area	Personnel	Pre-cursor item
1	Define coexistence use cases	Cameron Gillis c.gillis@sea.samsung.com Shahzad Bashir shahzad.bashir6@t-mobile.com	-
2	• Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc • Identify existing mechanisms creating intra-band interference and governing parameters • Identify existing interference mitigation techniques and governing parameters	Ramneek Bali Ramneek.Bali@charter.com Masoud Olfat masoud.olfat@federatedwireless.com Ariful Hannan Ariful.Hannan@commscope.com Raj Sengupta <RSengupta@ctia.org>	-
3	Evaluate lessons learnt from global TDD deployments and their efficacy in the US	Raj Sengupta <RSengupta@ctia.org>	-
4	Perform deterministic and statistical analyses for the agreed-upon use cases in the areas of:	-	-
4a	Asynchronous TDD operation	Ramneek Bali Ramneek.Bali@charter.com Masoud Olfat masoud.olfat@federatedwireless.com	1, 2
4b	Out of band emissions	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4c	Receiver overload and co-location	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4d	Non-3GPP solutions	Need Lead with subject matter expertise Masoud Olfat can support but need lead masoud.olfat@federatedwireless.com	1, 2
5	Examine potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions	Mark Gibson mgibson@comsearch.com Masoud Olfat masoud.olfat@federatedwireless.com Andy Clegg aclegg@google.com	

END.
Sincerely,
TWG-4 (3.7 GHz service / CBRS coexistence) Co-chairs:
PJ.Jayawardene@charter.com (PJ Jayawardene).
peter.tenerelli@verizon.com (Pete Tenerelli)
FCC-C-Band-TWG4@googlegroups.com (e-mail list)

f. 7-17-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 7/17/2020, 1:30pm, Eastern Time

ACTIONS

- **Ramneek, Masoud, Ariful, and Raj** to recommend parameters for the group's consideration. Reference: volunteer table below: Item 2 *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc*
- Requesting **members** to volunteer to carry out required tasks for the working group. See Table below for volunteer slots highlighted in yellow
- **Existing Volunteers** can continue working in their respective areas
- **ALL**: Next meeting Friday July 24th 1:30 – 2:30 pm, Eastern Time.

TODAY'S MEETING

- **TDD Sync with Non-3GPP solutions.** Following up on Masoud's presentation on this topic last week…

Discussion:

- In the CBRS band, there are effectively two non-3GPP air interfaces operating, Cambium's technology (using a proprietary interface) and WiMAX technology. There are other vendors who could, but have not, entered the CBRS market.
  Required next steps include feasibility study (complete for Cambium, in-progress for WiMAX), followed by protocol development by CBRS Alliance or Winnforum.

- **Review findings / recommendations** of Item 2 from the volunteer table: *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc.*

Discussion:

- Thus far, key parameters are based upon FCC/3GPP limits, for example for OOBE, transmitted power.
- How to meet the mandate of the TWG to analyze with realistic equipment parameters, and provide insights beyond already published analyses?
  Possibilities include:
  - Use information on the public record in the proceedings
  - Consider equipment transmit / receive specs from operational 2.5 GHz band
  - Use sensitivity analysis to compare the impact of different parameter values, relative to regulatory limits.
- What are typical CPE powers by morphology type? Can SAS providers assist?
- Question about suitability of radio propagation model. We'll consider a proposal for a different one.
- Group to provide further conversation over e-mail

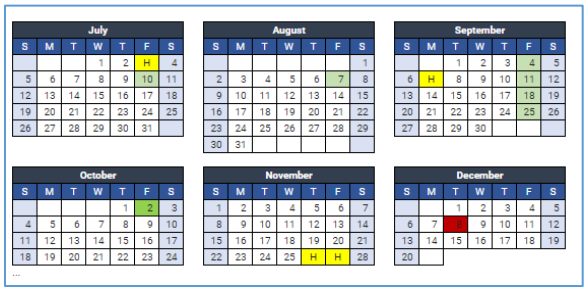
- **Topics for next meeting**
  - Review findings / recommendations of the Item 2 from the volunteer table *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc.*

REPRESENTED ON TODAY'S CALL

Charter	Comcast	Commscope	CTIA
Ericsson	Federated Wireless	Google	NCTA
Nokia	Samsung	T-Mobile	Verizon
Windstream	WISPA		

- **Schedule for Completion of SoW.** This schedule is based upon the Working Group's Statement of Work, working backwards from a Oct 2nd completion date:

Date	Milestone
10-Jul	Lock down list of use cases
7-Aug	SOW item 3 [Quantifying the impacts of the areas of concern] complete
28-Aug	SOW item 4 [Coexistence options] complete
4-Sep	SOW item 5 [Coexistence management and coordination] complete
11-Sep	SOW item 6 [enforcement of coexistence] complete
18-Sep	Recommendations finalized and drafted
25-Sep	Final Review of recommendations
2-Oct	TWG Recommendations submitted to OET
8-Dec	C-Band auction



Notes:
- Current SoW version is version 1.4

VOLUNTEER TABLE:

Item	Work area	Personnel	Pre-cursor item
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4c	Receiver overload and co-location	Ramneek Bali Ramneek.Bali@charter.com	1, 2
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END.
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peter.tenerelli@verizon.com (Pete Tenerelli)
FCC-C-Band-TWG4@googlegroups.com (e-mail list)

g. 7-24-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 7/24/2020, 1:30pm, Eastern Time

ACTIONS

- **Ramneek, Masoud, Ariful, and Raj** to recommend parameters for the group's consideration. Reference: volunteer table below: Item 2 *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc*
- **ALL**: We are seeking parameter values for analysis. Seeking alternate analysis methods based on comments on this meeting. See Discussion section below.
- Requesting **members** to volunteer to carry out required tasks for the working group. See Table below for volunteer slots highlighted in yellow
- **Existing Volunteers** can continue working in their respective areas
- **ALL**: Next meeting Friday July 31st 1:30 – 2:30 pm, Eastern Time.

TODAY'S MEETING

- **Review findings / recommendations** of Item 2 from the volunteer table: *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc.*

Discussion:

- **Latest version of the analysis parameters**. Ramneek presented the latest version of the parameters in an excel-based static calculator. He also distributed it to the group via e-mail.
  - The end result in the spreadsheet is an isolation in dB and distance.
  - Thus far, key parameters are based upon FCC/3GPP limits, for example for OOBE, transmitted power. However, it is possible to change parameters values, see drop-down lists in spreadsheet.
  - The sub-group is seeking help with values for interference reductions due to beamforming, transmitting at powers below the maximum allowed, and any other mitigation techniques.
- **Applicability of the analysis.** There was various discussions about the applicability of the analysis underway:
  - **3GPP Blocking Spec**. Kumar stated that the 3GPP blocking spec used in our analysis is meant for the certification of equipment, and is not related to network performance in the field. He suggests rather that a capacity simulation is in order, calculating throughput reductions. He raised the question of a similar interference problem within CBRS can already occur between Cat A and Cat B CBSDs – asking when CBRS doesn't have the TDD alignment, should we impose these restrictions on an adjacent band (C-Band)?
  - **Caveating of findings.** Cameron and others stated that any findings must be fully caveated as to their limitations, applicability, gaps, and concerns.
  - **6 dB interference spec.** Gary stated that the 6 dB spec is an equipment testing spec, and does not mean the receiver will get desensitized. He views this as a corner case and

stated that the use of this value doesn't indicate how frequently this situation could occur. He contrasted our current analysis method with a standardized 3GPP method that quantifies how often unacceptable degradation would occur in a given scenario. He said that the 3GPP method assumes a synchronized TDD.
    - **Current set of parameter values.** Navin states that the current set of parameter values are suitable for worst-case.
    - **Monte Carlo simulations**. Masoud asks about the set of assumptions/values to use for a Monte Carlo simulation. Gary replies that the proper method is to parametrize the ACLR and observe the throughput degradation as your vary ACLR. Then decide when the degradation becomes unacceptable.
- **Co-chairs comments**.
    - Agree that results should be caveated.
    - If the group has recommendation for alternate methods for performing the analysis, please provide them
    - Request that the first pass of the static analysis be presented next meeting

TOPICS FOR NEXT MEETING

- Review findings / recommendations of the Item 2 from the volunteer table *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc.*
- Preview of global TDD deployments. (tentative or time-permitting)

REPRESENTED ON TODAY'S CALL

Cable Labs	Charter	Comcast	Commscope
CTIA	Ericsson	Federated Wireless	Google
Nokia	Samsung	T-Mobile	Verizon
Windstream	WISPA		

- **Schedule for Completion of SoW.** This schedule is based upon the Working Group's Statement of Work, working backwards from a Oct 2nd completion date:

Date	Milestone
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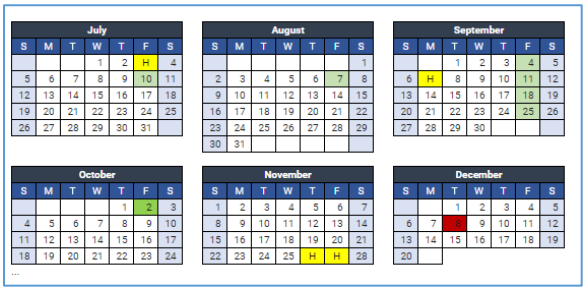
25-Sep	Final Review of recommendations
2-Oct	TWG Recommendations submitted to OET
8-Dec	C-Band auction



Notes:

- Current SoW version is version 1.4

VOLUNTEER TABLE:

Item	Work area	Personnel	Pre-cursor item
1	Define coexistence use cases	Cameron Gillis c.gillis@sea.samsung.com Shahzad Bashir shahzad.bashir6@t-mobile.com	-
2	• Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc • Identify existing mechanisms creating intra-band interference and governing parameters • Identify existing interference mitigation techniques and governing parameters	Ramneek Bali Ramneek.Bali@charter.com Masoud Olfat masoud.olfat@federatedwireless.com Ariful Hannan Ariful.Hannan@commscope.com Raj Sengupta <RSengupta@ctia.org>	-
3	Evaluate lessons learnt from global TDD deployments and their efficacy in the US	Raj Sengupta <RSengupta@ctia.org>	-
4	Perform deterministic and statistical analyses for the agreed-upon use cases in the areas of:	-	-
4a	Asynchronous TDD operation	Ramneek Bali Ramneek.Bali@charter.com Masoud Olfat masoud.olfat@federatedwireless.com	1, 2
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4c	Receiver overload and co-location	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4d	Non-3GPP solutions	Need Lead with subject matter expertise Masoud Olfat can support but need lead masoud.olfat@federatedwireless.com	1, 2

Item	Work area	Personnel	Pre-cursor item
5	Examine potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions	Mark Gibson mgibson@comsearch.com Masoud Olfat masoud.olfat@federatedwireless.com Andy Clegg aclegg@google.com	

END.
Sincerely,
TWG-4 (3.7 GHz service / CBRS coexistence) Co-chairs:
PJ.Jayawardene@charter.com (PJ Jayawardene).
peter.tenerelli@verizon.com (Pete Tenerelli)
FCC-C-Band-TWG4@googlegroups.com (e-mail list)

h. 7-31-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 7/31/2020, 1:30pm, Eastern Time

ACTIONS

- **ALL**: We are seeking further assistance and/or insights into existing TDD deployment methods/parameters. Contact Raj to assist.
- **Ramneek, Masoud, Ariful, and Raj** to recommend parameters for the group's consideration. Reference: volunteer table below: Item 2 *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc*
- **ALL**: We are seeking parameter values for analysis. Seeking alternate analysis methods based on comments at our July 24th meeting.
- Requesting **members** to volunteer to carry out required tasks for the working group. See Table below for volunteer slots highlighted in yellow
- **Existing Volunteers** can continue working in their respective areas
- **ALL**: Next meeting Friday August 7th 1:30 – 2:30 pm, Eastern Time.

TODAY'S MEETING

- **A Preview** of Item 3 from the volunteer table: **Evaluate lessons learnt from global TDD deployments and their efficacy in the US**
- **Analysis Parameters work continues.** We will return to this week of August 3rd

Discussion:

- **A preview of global TDD.** Raj presented a draft of his research and analysis of mid-band TDD deployments globally.
    - Thus far, the survey includes eight 4G deployments and five 5G deployments (some still to-be-deployed)
    - The survey examined Allocated Band(s), License(e)s, Duplex Scheme, Guard Band Usage, TDD Coordination Method. PJ requests that Raj include information on up/down ratios and use cases.
    - The networks are in the 2, 3, and 4 GHz bands, using TDD. Guard bands are not used except in one 4G case. In 5G networks, operator coordination is the method of deciding TDD parameters with the Chinese regulator involved in organizing the negotiations. In 4G networks, there was more regulator involvement including three mandating a set of TDD parameters.
    - There were a few examples of allowed exceptions to the determined TDD parameter set. Cameron, Manish asks for information on how those decisions were made.
    - ITU work on this topic in nascent stage.

- Separate, but related: CBRS Alliance agreed to begin a work item to study TDD sync of non-3GPP and 3GPP networks.

TOPICS FOR NEXT MEETING

- Review findings / recommendations of the Item 2 from the volunteer table *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc.*

REPRESENTED ON TODAY'S CALL

CCA	Charter	CTIA	Ericsson
Federated Wireless	Nokia	Samsung	T-Mobile
Verizon	Windstream		

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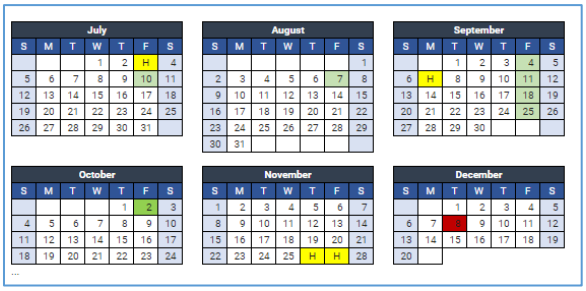

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FCC-C-Band-TWG4@googlegroups.com (e-mail list)

i. 8-7-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 8/7/2020, 1:30pm, Eastern Time

ACTIONS

- **ALL**: We are seeking further assistance and/or insights into existing TDD deployment methods/parameters. Contact Raj to assist.
- **Ramneek, Masoud, Ariful, and Raj** to recommend parameters for the group's consideration. Reference: volunteer table below: Item 2 *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc*
- **Raj:** Continue work on existing TDD deployment methods/parameters.
- **ALL**: We are seeking parameter values for analysis. Seeking alternate analysis methods based on comments at our July 24th meeting.
- Requesting **members** to volunteer to carry out required tasks for the working group. See Table below for volunteer slots highlighted in yellow
- **Existing Volunteers** can continue working in their respective areas
- **ALL**: Next meeting Friday August 14th 1:30 – 2:30 pm, Eastern Time.

TODAY'S MEETING

- **Review findings / recommendations** of Item 2 from the volunteer table: *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc.*

Discussion:

- **Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc.** Ramneek and team review the latest analysis spreadsheet.
    - We reviewed the static analysis that considers the worst-case scenarios, examining base station to base station interference potential. The output of the analysis yields isolation values in dB. A distance is also calculated, based on a radio propagation model.
    - There is an "adjusted" value that uses a dB correction factor to account for the benefit from the use of beamforming antennas. The value used in today's presentation was 25 dB. The "adjusted" results are shown with a suffix of "_A".
    - We focused on the *C-Band to CBRS ACIR vs. Isolation chart* and examined the isolation distances required, specifically in the ACIR range of 35-40 dB.
        - We discussed how to use this data. Cameron suggested that we could use this data to understand where bounds may exist. We discussed that the urban LOS case was unlikely given the expected antenna heights and obstructions that tend to exist in urban areas.
        - We discussed applicability of the use case. Including: vertically stacked tower colocation would not apply to the analysis. On the other hand, a rooftop colocation could have antennas pointing toward each other and use such an analysis. Kumar stated that the peak gain of the data channel (~18-24 dB) is a

stochastic event and does not happen all the time, and it was unclear what is the effect out of band – he felt like the effects captured in the analysis were pessimistic (e.g. more interference)

- Ramneek summarized that there is some isolation distance required in this scenario for each of the propagation modes. Kumar suggested comparing the C-Band interference to intra-CBRS interference to understand if the C-Band could interfere more than already exists within CBRS.

- Currently, a Monte Carlo (statistical) toolset is not available.

TOPICS FOR NEXT MEETING

- Navin to present Nokia simulations CBRS / C-Band Coexistence
- Further Preview of global TDD deployments.

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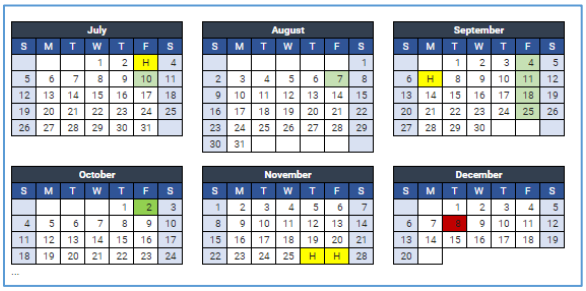

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FCC-C-Band-TWG4@googlegroups.com (e-mail list)

j. 8-14-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 8/14/2020, 1:30pm, Eastern Time

ACTIONS

- **ALL**: We are seeking further assistance and/or insights into existing TDD deployment methods/parameters. Contact Raj to assist.
- **Ramneek, Masoud, Ariful, and Raj** to recommend parameters for the group's consideration. Reference: volunteer table below: Item 2 *Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc*
- **Raj:** Continue work on existing TDD deployment methods/parameters.
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- Requesting **members** to volunteer to carry out required tasks for the working group. See Table below for volunteer slots highlighted in yellow
- **Existing Volunteers** can continue working in their respective areas
- **ALL**: Next meeting Friday August 21st 1:30 – 2:30 pm, Eastern Time.

TODAY'S MEETING

- **C-Band / CBRS Coexistence: Dynamic Simulation Results**. Presented by Luca Rose, Nokia Bell Labs

Discussion:

- **C-Band Performance Impacts to CBRS: Dynamic Simulation Results.** Luca Rose presented the simulation outcomes.
- **Scenarios**: Analysis examined three scenarios using different amounts of synchronization.
  - Worst case scenario simulations
  - CBRS and C-Band always had traffic to send-- "full buffer" transmissions

Scenario	CBRS Downlink↓	CBRS Uplink↑	C-Band Downlink↓	C-Band Uplink↑	Comments
100% Unsynched TDD	0%	100%	100%	0%	Won't occur in the field, provides boundary condition.
Semi-Synched TDD	70%	30%	30%	70%	50% probability of frame collision
Fully Synced TDD	70%	30%	70%	30%	Co-sited BSs. Vertical separation 5m

- **Scenario Variables**: In each scenario, the analysis examined the impact of:
  - **Varying ACIR** (Adjacent Channel Interference Ratio) {46 dB, 58 dB}

- **Varying distance** between CBRS and C-Band sites {100m, 300m}. Note: Co-sited, fully synched scenario used a 5m *vertical* separation.

  Baseline case was also included for comparison: Only CBRS is operating (no C-Band transmissions).

- **Analysis Outputs:**
  - **CBRS Throughput** impacts (uplink, downlink)
  - **Packet loss** at cell-center and cell-edge
- **Conclusions**:
  - CBRS Downlink not degraded in any scenario, rather degradation appears in CBRS uplink in the absence of full synchronization.

	Degradation on CBRS Uplink Throughput relative to (CBRS-only) Baseline. Per {ACIR, CBRS/C-Band BS Separation}		
Scenario	**{58 dB,300m}**	**{58 dB,100m} & {46 dB,300m}**	**{46 dB,100m}**
Fully Unsynchronized:	Minimal degradation	Slight degradation. "12 dB ACIR buys you 200m or vice versa"	Substantial degradation:
Semi-Synchronized:	No degradation	Slight degradation: "12 dB ACIR buys you 200m or vice versa"	Substantial degradation:
Fully synchronized, Co-sited:	No degradation rel. to baseline for both 46 dB and 58 dB ACIR		

- **Questions/Clarifications.**
  - Interference limited system in this analysis with intra-system ISD of 500 m
  - Throughput more meaningful metric than interference level
  - Q: Sensitivity of the vertical separation distance in the co-sited analysis. A: Luca expects that the CBRS and C-Band BSs could be closer, but only with sync.
  - Q: In the semi-sync case, isn't there still UE to UE interference? A: Yes, however the rate of occurrence is low. Part of the reason for the low amount of UE to UE interference is the benefit given by power control.
  - Q: Sensitivity to antenna height in the analysis. A: (Luca) doesn't expect that this will have a noticeable impact on the results. The height is most influential in determining the Probability (LOS, NLOS)
  - Q: Sensitivity of the C-Band EIRP? In the analysis, EIRP is 5 dB below the maximum permitted in the FCC rules. A: (Luca) don't expect much impact with 5 dB higher radiated power. Also, the 500m ISD scenarios are interference limited, where maximum transmit powers would not be used.
  - Q: Regarding the semi-sync scenario. In the conclusion, it says that 46 dB ACIR and 300m is sufficient protection. In the literature, I've seen 25-30 dB ACIR considered to be acceptable. Is 46 dB realistic? A: Yes, 46 dB is realistic. We are familiar with CBRS performance; the CBRS Adjacent Channel Selectivity (ACS) is the limiting factor.
  - Q: bandwidth of C-Band signals. A: 20 MHz. Revised presentation to follow and will update this information.

TOPICS FOR NEXT MEETING

- Interference analysis for synchronized TDD operation
- (tentative) Further Preview of global TDD deployments.

REPRESENTED ON TODAY'S CALL

AT&T	Cable Labs	Charter	Comcast
Commscope	CTIA	Ericsson	Federated Wireless
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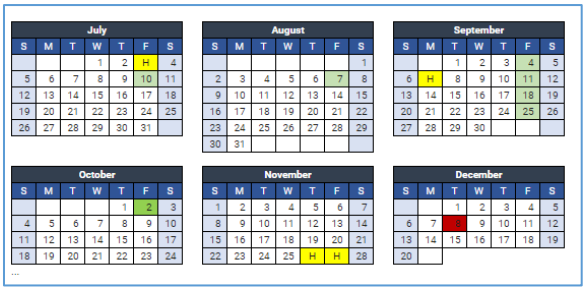

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k. 8-21-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 8/21/2020, 1:30pm, Eastern Time

ACTIONS

- **ALL**: We are seeking further assistance and/or insights into existing TDD deployment methods/parameters. Contact Raj to assist.
- **Raj:** Continue work on existing TDD deployment methods/parameters.
- **Pete/PJ**: Draft TWG4 deliverable framework.
- Requesting **members** to volunteer to carry out required tasks for the working group. See Table below for volunteer slots highlighted in yellow
- **Existing Volunteers** can continue working in their respective areas
- **ALL**: Next meeting Friday August 28th 1:30 – 2:30 pm, Eastern Time.

TODAY'S MEETING

- **Change of direction for this TWG4.** Details below**.**
- **Can TDD synchronization help reduce interference between CBRS/C-Band?** Details below
- **Measurements in an unsynchronized TDD CBRS Network.** By Mark Poletti, Cable Labs. Details below.

- **Change of direction for this TWG4**

Our self-imposed deadline of Oct 2nd, 2020 is fast approaching and this warrants a change in direction for the working group. In order to achieve as many Statement of Work (SoW) items as possible, we will shift from the analysis of work on *Quantifying the impacts of the areas of concern* (including calculating amounts of interference and required isolation).

We will shift our focus toward a deliverable to address work done thus far. In parallel, we will examine the remaining items on the SoW (attached):

- #4 Coexistence Options
- #5 Coexistence Management and Coordination
- #6 Enforcement of Coexistence Practices

The **deliverable (report)** can be described very generically as a list of what we agree upon and what we don't. We will work toward identifying areas of agreement. When we cannot reach agreement on a certain item, we will try to find a more general position where agreement might be possible.
We will insert findings/decisions from the work already done in the working group.

During the week of 8/24-8/28/20, we will draft a framework for the deliverable for review by the group.

- **Can TDD synchronization help reduce interference between CBRS/C-Band?**

We asked this question to the group in order to tee up this important topic for the TWG. We have general consensus that TDD Synchronization could help reduce interference between the bands. Some discussion followed:

- Shahzad described TMO's **(Sprint's) experience with TDD in the 2.5 GHz** band stating that unsynched operation in adjacent channels tended to be problematic, while operation with further spectral separation tended to be less of a problem. He suggested mitigations that are useful include separation distance, spectral separation (although not for blocking), antenna pointing, and beamforming.
- We discussed the pros and cons of **solving/preventing interference by disclosing base station locations or TDD sync parameters** of the respective licensees. We discussed that either option reveals something about the licensee's business strategy, to varying degrees.
  Shahzad stated that knowledge of each other's base stations could accelerate resolution of an interference problem. Joe stated that the complexities of multiple companies deploying in multiple bands would be better served by aligning on the TDD parameters in advance.
- PJ raised the idea of an **interference coordination framework**. Perhaps there would be an entity to contact?
- Raj discussed **TDD sync in the UK,** saying that they have a default configuration and a semi-synchronized option.

- **Measurements in an unsynchronized TDD CBRS Network.**

Mark Poletti presented results from a measurement campaign that assessed performance within an unsynchronized TDD CBRS Network.

- **Layout**:
  - 1x Victim CBSD outdoor
  - 4x Aggressor CBSDs indoors
  - 3x Aggressor CBRS UEs indoor
  - 1x Victim CBRS UE indoor
- **Scenario Variables**: In the measurements and processing, the analysis examined the impact of:
  - **Synch'd vs Unsynch'd:** {Aggressor & Victim TDD 0, Aggressor TDD2/Victim TDD 0}
  - **Varying distance** between the victim and aggressor
    - Indoor to Indoor {0.5, 10, 20m}
    - Indoor to Outdoor {4, 10, 20m}
  - **Varying "Guardband**": {no guardband (i.e. adjacent channel), 10 MHz, 20 MHz}

- **Analysis Outputs:**
  - **CBRS Throughput** and impacts
    - Synchronized performance was similar regardless of guardband/separation distance
    - General trend was in unsynchronized networks was:
      - Throughput degradation decreased with increasing distance
      - Throughput degradation decreased with increasing guardband size. Once the separation distance was large enough, the degradation ceased to exist.
- **Conclusions**:
  - For unsynchronized networks, distance and spectral separation are useful mitigation techniques.
  - There was discussion about the applicability of these measurements to the working group mandate of CBRS/C-Band coexistence. The Group discussed that the general trends are likely similar, even if the quantitative results would vary.

TOPICS FOR NEXT MEETING

- Review of TWG4 deliverable framework
- Further discussion of TDD sync options.

REPRESENTED ON TODAY'S CALL

AT&T	Cable Labs	Charter	Comcast
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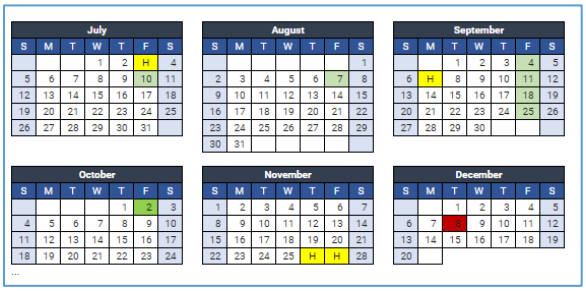

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3	Evaluate lessons learnt from global TDD deployments and their efficacy in the US	Raj Sengupta <RSengupta@ctia.org>	-
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4b	Out of band emissions	Ramneek Bali Ramneek.Bali@charter.com	1, 2
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5	Examine potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions	Mark Gibson mgibson@comsearch.com Masoud Olfat masoud.olfat@federatedwireless.com Andy Clegg aclegg@google.com	

END.
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peter.tenerelli@verizon.com (Pete Tenerelli)
FCC-C-Band-TWG4@googlegroups.com (e-mail list)

l. 8-28-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 8/28/2020, 1:30pm, Eastern Time

ACTIONS

- **ALL**: Provide comments on the deliverable framework document.
- **Raj:** Continue work on existing TDD deployment methods/parameters.
- Requesting **members** to volunteer to carry out required tasks for the working group. See Table below for volunteer slots highlighted in yellow
- **Existing Volunteers** can continue working in their respective areas
- **ALL**: Next meeting Friday September 4th 1:30 – 2:30 pm, Eastern Time.

TODAY'S MEETING

- **Review of TWG4 deliverable framework.** See below.
- **Further discussion of TDD sync options.** See below

- **Review of TWG4 deliverable framework** (See also attachment)

We reviewed version 01 of the framework for the deliverable to the FCC. The report will summarize our recommendations, findings, outcomes in the front part of the report, including [Recommendations], [Areas of Agreement], [Areas of disagreement], [Commentary for context and understanding].

One objective is to identify as many areas of agreement as possible, being as specific as possible. When we cannot agree on something specific, we will try to agree on something more general.

The report will structure is organized by the SoW topics:

1. Identify and Confirm Areas of Concern
2. Define Use Cases
3. Quantifying the impacts of the areas of concern
4. Coexistence options
5. Coexistence management and coordination
6. Enforcement of coexistence practices

Later sections in the report provide more detailed technical information, followed by appendices with all of our previous work and meeting minutes.

- **Further discussion of TDD sync options.**

Raj presented various pieces of information from his investigation into TDD sync options. He will follow up with more information next week. Notes from his presentation and discussion:

- Raj: Japanese operators should agree in advance on TDD configuration. Base stations must support this decided-upon configuration to have permission to operate.
- Raj: China decided upon DDDSU pattern as negotiated by the operators in adjacent spectrum within the 3.5 GHz band.
- Raj: In general across all countries, operators are deciding which TDD parameters to use
- Masoud: Cambium TDD sync is flexible to adapt to sync with other technologies.
- Raj: GSMA recommends to define default national TDD parameters before award
- Several discussion points about 4G TDD methods were discussed.
- Q: Question about should a single TDD parameter set be required nationwide?
- A: Shahzad. No. One configuration doesn't allow sufficient flexibility for different applications. For example, during coronavirus pandemic, there is now more uplink traffic than previously. There are niche markets for IOT or latency sensitive applications. Interference does not occur all of the time in unsynchronized networks, rather when the base stations are close to each other with filters that have a more gradual roll off characteristics.
- A: PJ. Japan allows operators to address interference locally, as presented by Nokia, presented earlier in the TWG4.
- A: Cameron. We should encourage a hybrid solution with the majority using a standard TDD configuration then have the option to use something different. Agrees with Nokia (what exactly was this?) Cameron also mentioned the possibility of using Japan's method where operators can flip the Up/down slots and take the interference risk.
- Should we consider the possibility of a default parameter set for C-Band 5G-NR macro cells with the option to use a non-default pattern in some areas?

TOPICS FOR NEXT MEETING

- Comments on TWG4 deliverable framework
- Further discussion of TDD sync examples, recommendation and US-specific constraints

REPRESENTED ON TODAY'S CALL

Charter	Comcast	Commscope	CTIA
Ericsson	Federated Wireless	Google	Nokia
Samsung	T-Mobile	US Cellular	Verizon
WISPA			

- **Schedule for Completion of SoW.** This schedule is based upon the Working Group's Statement of Work, working backwards from a Oct 2nd completion date:

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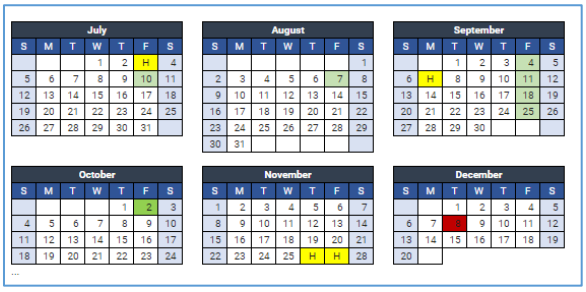
18-Sep	Recommendations finalized and drafted
25-Sep	Final Review of recommendations
2-Oct	TWG Recommendations submitted to OET
8-Dec	C-Band auction



Notes:

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m. 9-11-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 9/11/2020, 1:30pm, Eastern Time

ACTIONS

- **ALL**: Provide comments on the deliverable framework document.
- **ALL:** Prepare to discuss TDD Sync notification and coordination.
- **ALL**: Next meetings:
  - Friday September 18th 1:30 – 3:30 pm, Eastern Time.
  - THURSDAY, Sept 24th 11 am – 1 pm, Eastern Time (DATE & TIME CHANGE)
  - Friday October 2nd, 1:30 – 3:30 pm, Eastern Time (back to normal time)

TODAY'S MEETING

- **Considering the impact of relative levels of network loading on CBRS / C-Band coexistence.** Presentation by Chrys Koutsimanis**.** See below.
- **TDD Synchronization survey and discussion**. Presentation by Raj Sengupta See below.

x----------x

- **Considering the impact of relative levels of network loading on CBRS / C-Band coexistence.** (See also attachment)

Chrys presented coexistence analysis of C-Band and CBRS networks that are fully synchronized (different than most scenarios examined by the TWG4).

The simulation examined the impact of varying the relative network utilization levels in the respective networks:

- It looked at interference levels within CBRS (with C-Band "switched off").
- Next, it examined the impact of C-Band on the CBRS network for both Cat A and Cat B.

Regarding the network elements:

- **CBRS base stations** were Outdoor (Cat A & Cat B) and the **CBRS UEs** were both indoor & outdoor.
- **C-Band base stations** were outdoor macro.

Findings:

- In all cases, the degradation to capacity was on the downlink, but not on the uplink.
- When the C-Band is the aggressor, a very high network utilization (~90%) is needed to severely impact CBRS. The interference levels are manageable under typical network scenarios. Modifying the relative antenna orientations of the victim/aggressor has a significant positive impact in reducing interference.
- In this study, the cell edge targets were 5 Mbps downlink, 1 Mbps uplink

- **TDD Synchronization survey and discussion.** (see also attachment)

Raj presented some common themes of TDD synchronization based on his investigation of other countries.

- As shown in the slides, some countries have a preferred TDD pattern.
- Some countries have an alternate configuration as well. The UK has a primary and alternate TDD pattern with a permissive and restrictive mask, respectively.
- Most common special slot configurations are:
    - Without incumbents present in the band 10:2:2 (Downlink: guard period: uplink symbols)
    - With incumbents present in the band 6:4:4 or 4:6:4 (Downlink: guard period: uplink symbols)

Discussion:
Should we define a default and alternate frame configuration? We did not reach a consensus on this point, with most commenters preferring not to have a default configuration.
We will continue the discussion next week addressing the question: If no default TDD configuration, then how would a notification/coordination mechanism work?

Here is the discussion from today's call.

- Masoud: asks the group to consider how to manage the control between a primary and alternate TDD configuration in C-Band. The CBRS Alliance is working on this for CBRS band
- Kumar: developing a coordination system before licensees are known may be a problem. Separately, it's possible that some non-3GPP CBRS users cannot synchronize.
- Ratul: There are TDD patterns that will work together and doing TDD sync coordination is business as usual. We don't want to choose a specific pattern. The TWG has helped to inform that common patterns are well defined.
- Masoud: Don't assume that CBRS cannot TDD align. We should assume that it is possible to achieve TDD synchronization within CBRS
- Manish: Coordination of TDD synchronization is not the same as FDD. It requires more rigor. We should learn from other countries experience.
- Navid: AT&T does not want to have a default TDD configuration
- Shahzad: Addressing TDD synchronization locally makes sense, rather than choosing a default configuration. This allows flexibility to implement what's needed based on business requirements. We can learn more about how coordination is done, including Japan.
- Ben: a framework for coordination is good idea. He raises the question about how GAA use cannot interfere with PAL uses within CBRS.
- Masoud: PAL uses are not entitled to OOBE protections within CBRS band. CBRS Alliance is working to address this.
- Kumar: There are no adjacent channel protections given to users within the CBRS band.
- Masoud/Kumar: CBRS Alliance is a good framework and it is not a mandate.
- Patrick: Verizon does not want to define a default TDD configuration
- Kara: CTIA, on behalf of ATT, TMO, Vz does not want to define a default TDD configuration
- Manish: The TWG should state that TDD synchronization is required. We need to figure out how to perform that.

- Pete: Thus far, the TWG4 has agreed that TDD synchronization could help to reduce cross-band interference between CBRS and 3.7 GHz service. To date, we haven't considered the question if TDD synchronization should be required.
- Shahzad: Describes a scenario where many base stations from both services are deployed. If opposite-band sites are nearby, the interference likelihood is higher. If they are far apart, less so. It's possible to solve the problems on a localized basis – if there is a small number of sites with problems, could make site-level changes like changing antenna azimuth or tilt. If widespread problems, then could use cross-band TDD synchronization.
- Manish: Waiting until an interference problem occurs is too late. In general, CBRS will deploy before 3.7 GHz service. This could result in sudden interference problems to CBRS operators when the 3.7 GHz service starts.
- Patrick: FCC takes a free-market approach to regulation. 3.7 GHz service operators expected to have a strong incentive to coordinate to avoid interference, esp. since it is bi-directional. Coordination among FDD operators is common, it may be different than TDD, but is manageable. We should work toward a notification system.

TOPICS FOR NEXT MEETING

- Discussion TDD synchronization notification and coordination method
- Review of the draft deliverable document

REPRESENTED ON TODAY'S CALL

AT&T	Cable Labs	Charter	Commscope
CTIA	Ericsson	Federated Wireless	Nokia
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Windstream			

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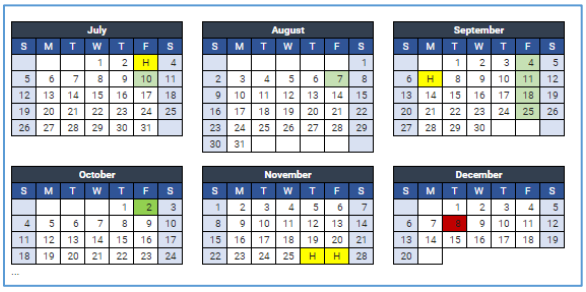

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9-18-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence
Meeting Minutes 9/18/2020, 1:30pm, Eastern Time

ACTIONS

- **ALL**: Provide comments on the draft TWG4 deliverable document. Rev 03 is already distributed. We will distribute Rev 04 early in the week of 9-21-20.
- **ALL**: Next meetings:
  - **THURSDAY, Sept 24th 11 am – 1 pm, Eastern Time** (DATE & TIME CHANGE): Review and on-screen editing of draft TWG4 report
  - **Friday October 2nd, 1:30 – 3:30 pm, Eastern Time** (back to normal time, final scheduled meeting): Final review and on-screen editing of draft TWG4 report

TODAY'S MEETING

- **Admin: upcoming schedule / document reviews.**
- **MEETING CHANGE NEXT WEEK ONLY: new time Thursday 9-24, 11-1 pm eastern**
- **Discussion TDD synchronization notification and coordination method**
- **Review of the draft deliverable document (we did not cover this item, deferring until next meeting.**

x----------x

- **Admin: upcoming schedule / document reviews.**

After today's meeting, the TWG4 will focus on review and completion of the deliverable document from this TWG. We intend to have this deliverable completed at the end of our TWG4 meeting on 10-2-2020. To meet this objective, we request members to provide feedback on the draft documents as we distribute them to the group. Revision 03 is already available, and we will distribute Revision 04 early in the week of 9-21-2020.

- **MEETING CHANGE TIME/DATE NEXT WEEK ONLY: new time Thursday 9-24, 11-1 pm eastern**

Next week's meeting will be on Thursday 9-24-2020 at 11 am – 1 pm, Eastern Time. We will hold the meeting one day earlier than usual, and at an earlier time of day. This is a one-time change.

- **Discussion TDD synchronization notification and coordination method**

On our previous meeting of 9-11-2020, we did not reach a consensus on the question of whether we should have a default set of TDD synchronization parameters. Therefore, today's meeting began with that context – if we don't have a default set of TDD synchronization parameters, then what should a CBRS / 3.7 GHz service coordination or notification mechanism look like?

The outcome of today's discussion was that we did not reach a consensus on answer(s) to today's question. The non-consensus items include the following: the timing for development of a coordination or notification mechanism, whether it made more sense to have a centralized vs. localized mechanism, whether or not a mechanism was required vs. normal course of business operations to solve cross-band interference problems, and the expected severity of cross-band interference problems. As a result, we don't have specific immediate-term recommendations on this topic, rather to recommend that an industry group continue to examine these questions in the future.

<u>The following are the discussion points raised by the group:</u>

PJ (opening question for the group's consideration): Should we have a mechanism to allow coordination / notification about TDD sync parameters among CBRS and 3.7 GHz service operators?

- Patrick: coordination / notification mechanism question needs to be separated into two parts: first the intra-C-Band should be figured out, followed by the inter-band portion (CBRS / C-Band)
- Masoud: (referencing intra-CBRS coordination) cannot rely on a static model. CBRS has a TDD coordination framework that is not part of the Part 96 rules
- PJ: the coordination mechanism must be dynamic
- Masoud: the dynamic nature of CBRS' coordination framework is due to the dynamic nature of CBRS itself.
- Ariful: In CBRS, there is a centralized control – users must register. This makes it easier to coordinate, but how to get it done?
- Andy C.: we could find a coordination mechanism, but it will be voluntary. With no regulatory requirement, it has no teeth. Consider that this TWG document could apply to the 3450-3550 band or other adjacent bands.
- Joe: Consider that lack of a coordination mechanism could hurt the value of the spectrum. It's good that we don't have a prescriptive regulator. Consider the value of operational predictability at the cost of some flexibility.
- Cameron: The focus should be on what are the triggers for coordination. It should be an overarching framework. It should include how to qualify interference, including how to identify the aggressor.
- PJ: (to the group) what should the triggers be for such a coordination / notification mechanism? For example, a certain amount/type of degradation? Who does the monitoring? Who to call? Is this solved on a national level or on a location level?
- Ratul: Triggers can be based on those used in the regular course of business. Affected parties exchange information as in a natural extension of license boundaries coordination. Triggers can be, for example. Throughput, retainability, accessibility, etc. If cross-band interference is the root cause, the affected parties can work it out.
- Joe A: There are common industry KPIs. Concern: if KPIs are used to trigger action, it, will not be straightforward to identify lack of TDD synchronization as the cause of the degradation.

- Cameron: Agrees that finding interference root cause could be difficult. He suggests a system that helps to propose root cause to performance problems or to propose a remedy. This system might work by having operators register network devices in a generalized way that would help determine root cause of interference, perhaps involving a sort of interference matrix. In response to a concern that operators often don't want to share information about their network infrastructure: this information repository could contain genericized information about the networks, that still have enough information to help make performance improvement recommendations, but not detailed enough to reverse engineer the more sensitive details.
- Joe: expects that interference problems related to unsynchronized TDD systems will be inside of the license area boundaries (not just limited to the boundary areas) Therefore, the problem will be worse than current license boundary area problems
- Shahzad: business as usual methods are the right way to deal with problems that might occur. Each operator has different KPIs. If their KPI(s) are exceeded, the operator should look into the problem on a site by site basis.
- Shahzad: regarding the database method of identifying the cause of interference, this isn't accurate to use a radio propagation model, measurements are more accurate.
- Cameron: (regarding the use of measurements instead of radio propagation calculations): this won't help for UEs, which are not tracked.
- Joe: (regarding the case-by-case resolution of interference problems without a TDD synchronization coordination mechanism): this is still labor-intensive and a better to have an up-front method
- Pete (to the group): let's consider the pros and cons of an up-front method vs. solving the problems as they appear.
- PJ/Pete summarize the conversation thus far: suggestions include:
    - business as usual methods of solving interference problems as they occur
    - Agreeing to a coordination / notification mechanism framework now
    - Agreeing to a coordination / notification mechanism framework when the C-band licensees are known.
    - A hybrid approach based on a set of tools that will help operators identify and resolve interference problems quickly when they occur.
- Raquel: We need to know the C-Band players and understand the problem better before deciding on a plan
- Pascale: Once the C-band auction is over, we will better understand the landscape of licensees and will understand the problem to be solved better. It may not be a problem. We can support a way to coordinate amongst the affected entities after the auction.
- PJ (asking Raquel and Pascale): We know that unsynchronized networks will cause degradation to varying degrees. What if the problem is multi-operator and complex? How to know who is operating in what area?
- Pascale: The affected entities will work in good faith to find a solution, using TDD synchronization or otherwise. The value of the TWG4 has been to identify where and when to use interference reduction methods

- Raquel: We've bounded the problem. The scope could become narrower and might be simple. Therefore, it doesn't make sense to try to address situation without knowing scope better.
- Patrick: It's too soon to develop a plan based on hypothetical circumstance. Wait until after the auction to do so.
- Colleen: It's clear that we don't know all the players, but have worked out that interference occurs
- Cameron: The best we can do at this point is to frame tools to mitigate interference from unsynchronized networks, including those from global operators.
- Shahzad: Interference problem solving should be worked out among the affected entities
- Manish: Global operators have already been dealing with TDD networks longer than we have. They agree that it is a problem but we cannot seem to. We should take their experience into account. TDD coordinating is not the same as FDD coordination – TDD is more complex. If you have other spectrum, then business as usual is fine. There is an interference problem with unsynchronized TDD and we should do something about it.
- Ratul: There are many different ways that we could evolve business as usual methods to accommodate this situation.
- Pascale: We've learned a lot from TWG4 and we will be prepared to put it to use.
- Manish: If we can figure out a method to address unsynchronized TDD interference, without exposing network element details, we should do it. If CBRS has deploys and later C-band comes on air, there could be interference. This is a big problem.
- Cameron: We don't have to mandate analysis, it shows that TDD sync is useful. In the future, we should follow global direction as other countries' networks utilization levels increase (and interference would be more likely). Propose that the idea of tools be separated from the question of mandates.
- Manish: All parties who will be C-Band licensees are already present in the TWG4, so we don't need to wait until later to address TDD synchronization coordination.
- Raj: TDD synchronization is a good idea and better done after the auction.
- Raquel: we'd be wise not to speculate on who will be the C-Band licensees.
- Navin: There are still issues to be resolved regarding PAL and GAA in the CBRS Alliance.
- Richard: One band shouldn't get to decide how the coordination will be done
- Gram: A useful tool might be 3GPP TR 38.866, Study on remote interference management for NR
- Cameron: Likes the idea of segmenting the discussion into tools vs. mandate
- PJ: (summarizing past TWG4 activity and looking forward) Mandating is no longer a viable option per the group's preference. We could look at a framework in the future.
- Ben: it could be useful to have a PLMN scanner as a troubleshooting device which could help identify the source of the interfering signal. This was also discussed in TWG1 (FSS/ 3.7 GHz service coexistence)

TOPICS FOR NEXT MEETING

- Review of the draft deliverable document

REPRESENTED ON TODAY'S CALL

AT&T	Charter	Comcast	Commscope
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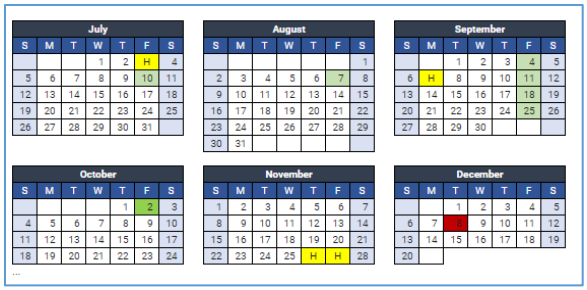

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5	Examine potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions	Mark Gibson mgibson@comsearch.com Masoud Olfat masoud.olfat@federatedwireless.com Andy Clegg aclegg@google.com	

END.
Sincerely,
TWG-4 (3.7 GHz service / CBRS coexistence) Co-chairs:
PJ.Jayawardene@charter.com (PJ Jayawardene).
peter.tenerelli@verizon.com (Pete Tenerelli)
FCC-C-Band-TWG4@googlegroups.com (e-mail list)

n. 9-24-2020 Meeting

Technical Working Group 4: 3.7 GHz service / CBRS coexistence

Meeting Minutes 9/24/2020, 11:00am, Eastern Time

ACTIONS

- **ALL**: Provide comments on the draft TWG4 deliverable document. See instructions below. You should have Rev 05 available for your review and comment. See e-mail with subject "*FINAL REVIEW of TWG4 Final Deliverable draft (rev 05) - LAST CHANCE TO MODIFY*", sent on 9-24-20 at 4:57 pm, Eastern Time.
- **ALL**: Next meeting:
  - **Friday October 2nd, 1:30 – 3:30 pm, Eastern Time** (back to normal time, final scheduled meeting): Final review and on-screen editing of draft TWG4 report

TODAY'S MEETING

- TWG4 deliverable document commenting, and reviews. LAST CHANCES TO COMMENT/MODIFY REPORT.
- Update: FCC Meeting with chairs of technical working groups on 9-22-20.
- Walk-through and request for comment on the TWG4 draft deliverable document

x----------x

1. TWG4 deliverable document commenting, and reviews.

TWG4 DELIVERABLE REPORT: LAST CHANCE TO MODIFY!
Please review and provide comments on the latest version of the TWG Deliverable report (rev 05).

- **HOW-TO?**: e-mail your comments. Preferably as tracked changes in MS Word. But we can accept them in an email, if you must. We'd prefer that you provide actual wording rather than something vague like "clarify section 12.6.3"
- **WHAT'S NEXT?:** PJ and I will consolidate the comments and re-circulate the document at the middle of next week. We will continue to take comments after the re-circulation.
- **WHEN IS THE FINAL REVIEW?: Friday 10-2-20**, we will do an on-screen editing session with all proposed comments ready for consideration. We will adjudicate the proposed changes. Meeting time is 1:30 – 3:30 pm, Eastern Time. We intend to have this deliverable completed at the end of our TWG4 meeting on 10-2-2020, with the exception of cosmetics.

- **WHAT HAPPENS AFTER FINAL REVIEW?:** Without modifying the content, we will format the report in a manner consistent with the multi-stakeholder group's (MSG) method of submission to the FCC. The MSG is the umbrella group coordinating the activities of the four C-band technical working groups. The exact submission date and format is to be determined. We've asked the FCC for feedback on these topics.

2. Update: FCC Meeting with chairs of technical working groups on 9-22-20.

On 9-22-20, the chairs of the four C-Band technical working groups and of the (umbrella organization) Multi-Stakeholder Group (MSG) met with FCC staff to provide progress updates and seek guidance. The MSG is chaired by Danielle Pineres (NCTA) and Kara Graves (CTIA). FCC staff were generally pleased with progress. Regarding next steps on TWGs report submissions format and TWG4 non-consensus items, the FCC staff said that they would have to get back to us. The MSG is submitting an ex parte filing about this meeting with the FCC.

3. Walk-through and request for comment on the TWG4 draft deliverable document.

We walked through the TWG4 draft deliverable document today and sought comments. There were not many comments since the group did not have much prior review time.
We made some changes as agreed to by the group and we marked some areas for further work, as discussed on the call. We used MS Word track changes and MS comments to highlight areas that are works-in-progress. We also used wording in [square brackets] to indicate tentative language. Please see instructions in item 1. above for proposing changes to the document and next steps.

TOPICS FOR NEXT MEETING

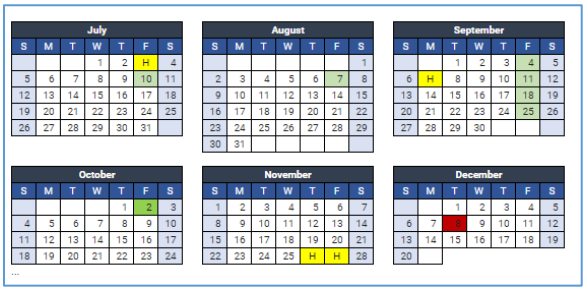
- Final review of the draft deliverable document and adjudication of proposed changes.

REPRESENTED ON TODAY'S CALL

AT&T	CCA	Charter	Comcast
Commscope	CTIA	Ericsson	Federated Wireless
NCTA	Nokia	Samsung	T-Mobile
US Cellular	Verizon	Windstream	WISPA

Schedule for Completion of SoW. This schedule is based upon the Working Group's Statement of Work, working backwards from an Oct 2nd completion date:

Date	Milestone
10-Jul	Lock down list of use cases
7-Aug	SOW item 3 [Quantifying the impacts of the areas of concern] complete
28-Aug	SOW item 4 [Coexistence options] complete
4-Sep	SOW item 5 [Coexistence management and coordination] complete
11-Sep	SOW item 6 [enforcement of coexistence] complete
18-Sep	Recommendations finalized and drafted
25-Sep	Final Review of recommendations
2-Oct	TWG Recommendations submitted to OET
8-Dec	C-Band auction



Notes:

- Current SoW version is version 1.4

VOLUNTEER TABLE:

Item	Work area	Personnel	Pre-cursor item
1	Define coexistence use cases	Cameron Gillis c.gillis@sea.samsung.com Shahzad Bashir shahzad.bashir6@t-mobile.com	-
2	• Determine realistic/reasonable equipment specifications/operational parameters and filter characteristics, etc • Identify existing mechanisms creating intra-band interference and governing parameters • Identify existing interference mitigation techniques and governing parameters	Ramneek Bali Ramneek.Bali@charter.com Masoud Olfat masoud.olfat@federatedwireless.com Ariful Hannan Ariful.Hannan@commscope.com Raj Sengupta <RSengupta@ctia.org>	-
3	Evaluate lessons learnt from global TDD deployments and their efficacy in the US	Raj Sengupta <RSengupta@ctia.org>	-
4	Perform deterministic and statistical analyses for the agreed-upon use cases in the areas of:	-	-

Item	Work area	Personnel	Pre-cursor item
4a	Asynchronous TDD operation	Ramneek Bali Ramneek.Bali@charter.com Masoud Olfat masoud.olfat@federatedwireless.com	1, 2
4b	Out of band emissions	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4c	Receiver overload and co-location	Ramneek Bali Ramneek.Bali@charter.com	1, 2
4d	Non-3GPP solutions	Need Lead with subject matter expertise Masoud Olfat can support but need lead masoud.olfat@federatedwireless.com	1, 2
5	Examine potential for negative impact on CBRS' Environmental Sensing Capability (ESC) system by C-Band transmissions	Mark Gibson mgibson@comsearch.com Masoud Olfat masoud.olfat@federatedwireless.com Andy Clegg aclegg@google.com	

END.
Sincerely,
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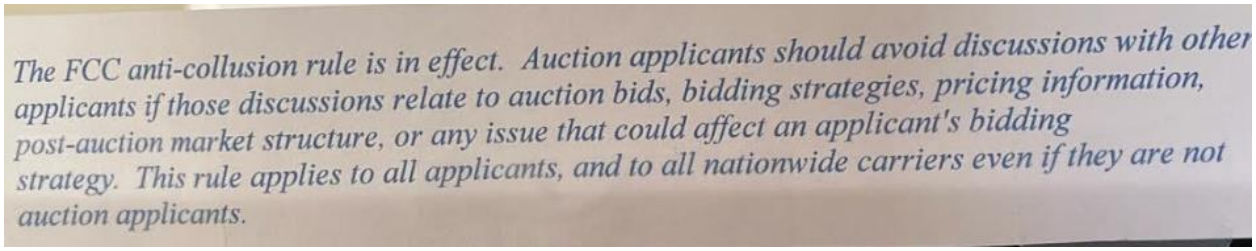
peter.tenerelli@verizon.com (Pete Tenerelli)
FCC-C-Band-TWG4@googlegroups.com (e-mail list)

o. 10-2-2020 Meeting

Technical Working Group 4 (3.7 GHz service / CBRS coexistence), October 2nd, 2020

AGENDA

- Roll call
- FCC Quiet Period Statement (C-Band Auction Quiet Period began 9-22-20)



- Agenda review and co-chair comments
- Progress recap from last week:
    - Update: FCC Meeting with chairs of technical working groups on 9-22-20.
    - Walk-through and request for comment on the TWG4 draft deliverable document

- Open Actions from last week
    - N/A

TODAY'S MEETING

- Final on-screen editing of the TWG4 report.
    - Today's goal
    - Current document status
    - Areas of focus
        - Top priority: content
        - Low priority: formatting
        - Don't plan to go through the meeting minutes (~60 pages)
        - Plans for review of non-consensus "opinion section"
        - Expectations for pace/mechanics of the review

- Next Steps
    - Formatting of report and submission via the multi-stakeholder group

- Any other business

Notes:

- Current SoW version is version 1.4

10. Appendix F: Attendees of TWG4 Meetings

The following people attended TWG4 meetings (alphabetically by company / organization):

Attendees of C-Band TWG4 meetings, 2020	
Name	**Company / Organization**
Navid Motamed	AT&T
Neeti Tandon	AT&T
Raquel Noriega	AT&T
Mark Poletti	Cable Labs
Roy Sun	Cable Labs
Alexi Maltas	CCA
Jonathan Levine	Charter
Colleen King	Charter
Erik Neitzel	Charter
Manish Jindal	Charter
PJ Jayawardene	Charter
Ramneek Bali	Charter
Lincy John	Charter
Brian Josef	Comcast
Joe Attanasio	Comcast
Andrew Beck	Commscope
Ariful Hannan	Commscope
Awaiz Ahmad Khan	Commscope
Mark Gibson	Commscope
Doug Hyslop	CTIA
Jen Oberhausen	CTIA
Kara Graves	CTIA
Raj Sengupta	CTIA
Gary Boudreau	Ericsson
Kumar Balachandran	Ericsson
Noman Alam	Ericsson
Stephen Rayment	Ericsson
Chrys Koutsimanis	Ericsson
Masoud Olfat	Federated Wireless
Mark Ayers	GCI
Andy Clegg	Google
Justin Terwee	Midco
Andy Scott	NCTA
Danielle Pineres	NCTA

Attendees of C-Band TWG4 meetings, 2020	
Name	**Company / Organization**
Fabiano Chaves	Nokia
Navin Hathiramani	Nokia
Prakash Moorut	Nokia
Luca Rose	Nokia
Gene Fong	Qualcomm
Cameron Gillis	Samsung
Rob Kubik	Samsung
Gram Lekutai	T-Mobile
Pascale Dumit	T-Mobile
Shahzad Bashir	T-Mobile
John Kay	US Cellular
Ratul Guha	Verizon
Max Solondz	Verizon
Patrick Welsh	Verizon
Pete Tenerelli	Verizon
Wes Burnett	Viaero
Ben Holden	Windstream
Richard Bernhardt	WISPA